COMMONWEALTH OF VIRGINIA

Green Infrastructure GIS

Year 1 Final Report

Prepared by:
Virginia Department of Conservation and Recreation
Division of Natural Heritage

Natural Heritage Technical Report 06-13
October 2006

DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

Green Infrastructure GIS

Year 1 Final Report

2006

Natural Heritage Technical Report 06-13

Virginia Department of Conservation and Recreation
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EXECUTIVE SUMMARY

The Green Infrastructure GIS Project is built upon the Virginia Conservation Lands Needs Assessment (VCLNA), an integrated assemblage of geospatial datasets and conservation prioritization guidelines, with the goal of implementing Green Infrastructure planning in the Virginia Coastal Zone

Green Infrastructure is an interconnected network of natural areas that conserve natural ecosystem functions, sustains clean air and water, and provides a wide array of benefits to humans and wildlife. This project is unique in that it involved major stakeholders early and throughout project implementation. With the guidance of a Green Infrastructure Advisory Workgroup, composed of key Coastal Partners, and based on technical and scientific methodology, DCR has identified, assembled, created and integrated three major Green Infrastructure models during the first of a two year project period. These models include:

Ecological Model – The Virginia Natural Landscape Assessment (VANLA) land cover was developed during this grant period by assembling, cross-walking, and merging RESAC 2000 imagery and several NLCD images. The resulting image was corrected for misclassifications of natural grass, agriculture, marshes, beaches, dunes, urban and barren classes. The VANLA land cover derivative is used as the base land cover throughout the VCLNA models. The VANLA land cover was analyzed to identify core areas and habitat fragments (a new feature type that includes patches of natural land with less interior area than cores but identified as an important conservation resource; this is a feature type tailored to the natural landscape of the Virginia Coastal Zone). Analyses were performed to create new data layers and add 45 prioritization attributes to the cores and habitat fragments shapefile.

Cultural Asset Model – The Cultural Asset Model was developed in collaboration with the Virginia Department of Historic Resources and represents spatial delineation of cultural areas of value in Virginia. The model is a compilation of archaeological sites, architectural sites and American Indian Areas, weighted to reflect a specific cultural value as determined by the Department of Historic Resources, then summed to represent a comprehensive cultural value.

Vulnerability Model – The Vulnerability Model is a GIS coverage that was developed from a series of statistical and GIS driven analyses to develop a predicted potential growth model. In an effort to map the predicted growth in Virginia and to put this growth into context in relation to the landscape, four models were developed: *Virginia Urban Vulnerability Model* showing predicted urban growth; *Virginia Urban Fringe Vulnerability Model* showing predicted growth at the urban fringe, or suburban growth; *Virginia Growth Outside the Urban Fringe Vulnerability Model* showing predicted growth outside the urban fringe, or rural growth; and *Virginia Vulnerability Model* showing a composite of all the vulnerability models integrated into one model representing growth pressures across the urban, suburban and rural landscape.

Maps and map images generated from the GIS models are available on CDs, which are easily distributable to localities and / or posted online. Currently, two GIS web applications are in the process of incorporating these products: Virginia Coastal GEMS and Virginia Natural Heritage Data Explorer. Additionally, more than 11 presentations

were given during the first year project period, introducing the concepts of Green Infrastructure GIS to more than 200 people at local, state, national and international levels.

The next step for the project is to develop additional GIS models that are critical to forming a comprehensive Green Infrastructure plan. Projected models are set to include a Forest Economics Model, a Recreational Model, a Hydrological Integrity Model, and, an Agricultural Model. Additionally, natural landscape corridors, blocks and a composite ecological prioritization theme will be developed to complete the Ecological Model. Detailed descriptions and documentation on the VCLNA and Green Infrastructure GIS are also available at http://www.dcr.virginia.gov/dnh/vclna.htm.

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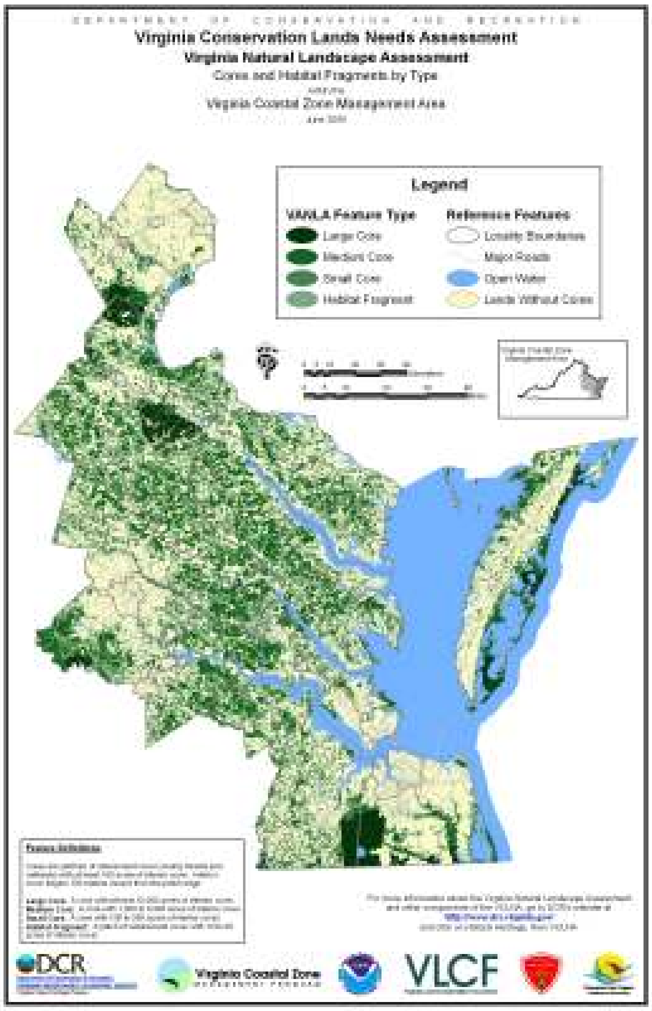


Virginia Department of Conservation and Recreation, Division of Natural Heritage
Virginia Coastal Zone Management Program

This work is funded by the Virginia Coastal Zone Management Program at DEQ through a grant from the National Oceanic and Atmospheric Administration to the Virginia Department of Conservation and Recreation's Natural Heritage Program.

INTRODUCTION

Habitat loss is the greatest threat to biodiversity in Virginia. Conversion of natural land covers to suburban and urban land uses is the primary mechanism by which habitat is lost permanently in Virginia. This conversion can occur in decentralized and scattered patterns, consuming an excessive amount of land and fragmenting the landscape; in the process destroying wildlife habitat and migration corridors, degrading water quality, and diminishing ecosystem functions. These patterns of suburban development exacerbate the amount of habitat fragmentation taking place and have far-reaching consequences for wildlife, especially species that are unable to adapt to fragmented landscapes and intolerant of disturbances associated with human activities.

As landscapes become more fragmented, large patches of natural land cover become less numerous. Large, unfragmented patches of natural cover have benefits that exceed the benefits of the same total area of natural cover distributed among smaller patches. Large patches are important not only in terms of wildlife and plant habitat, but also in terms of open space, recreation, groundwater recharge, maintenance of water quality, carbon sequestration, climate regulation, crop pollination, erosion control, sediment retention, and protection from storm and flood damage (Costanza et al. 1997). Such services are often overlooked as landscapes become developed. Traditional economic analyses that incorporate the financial benefits of development usually do not factor in ecological services, even though studies have estimated that these services contribute as much or more to the global economy as do marketplace processes (Costanza et al., 1997) and that they can result in a return on investment in excess of 100 to 1 when conserving natural land (Balmford et al. 2002).

Fragmentation of large patches of natural cover disproportionately removes interior habitat and increases the amount of edge. Resulting patches that are too small or too narrow may consist entirely of edge, making interior species more susceptible to edge effects. Edge effects include disturbance from humans, predation from opportunistic, adaptable, and generally more common wildlife species that operate well in suburban-forest ecotones, predation and harassment from pets, nest parasitism by brown-headed cowbirds (*Molothrus ater*), and competition for nest cavities with European starlings (*Sturnus vulgaris*). There are also environmental edge effects that include differences in wind velocity, temperature, light, and relative humidity (Harris 1984) that are most pronounced when the differences between forest height and the height of the surrounding land cover are greatest. For species dependent upon interior conditions, fragmentation often results in reduced population sizes and reduced diversity and in the most extreme cases it can result in local extirpations.

Patch isolation is another factor affecting species in fragmented landscapes. The degree of isolation is dependent not only on distance to other patches, but also the land covers surrounding the isolated patch. If the surrounding land cover, or matrix, is at least marginally suitable, then species might cross it to reach other patches. If the matrix is harsh to the species of interest, however, those species will be unlikely to traverse the matrix. Populations in the latter situation face an increased probability of inbreeding as genetic exchange between isolated populations of interior species decreases and thus are at risk of eventual extirpation. Local extrications also can result for seemingly healthy populations due to catastrophic weather events, sudden disease outbreaks, excessive predation, nest failure, and other causes. Once there is an extirpation, isolated patches are less likely to be recolonized naturally.

Landscape Corridors are valuable conservation tools (Bier and Noses 1998) that can attenuate the negative consequences of fragmentation, such as patch isolation, and help conserve metapopulations. A metapopulation can be defined as a population subdivided among different patches. Landscape Corridors have been shown to increase exchange of animals among patches and to facilitate dispersal of pollens and seeds (Tewksbury et al. 2002). The results of Damschen et al. (2006) support the use of corridors in biodiversity conservation. They found that habitat patches connected by corridors retain more native plant species than do isolated patches, that the difference increases over time, and that corridors do not promote invasion by exotic species. Important considerations of Landscape Corridors include length and width. Corridor width is positively correlated with abundance and species richness of birds, mammals, and invertebrates (Lindenmayer and Franklin 2002). Landscape Corridors should be used to connect large patches of natural land in fragmented landscapes to form a network of natural lands.

The Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH) is working on a project to develop a network of natural lands. This project, named the Virginia Natural Landscape Assessment (VANLA), is the main ecological component of the Virginia Conservation Lands Needs Assessment (VCLNA), the overarching project for which DCR-DNH has lead development responsibility and which models and maps various types of priority lands for conservation. The VANLA is a landscape-scale Geographic Information System (GIS) analysis for identifying, prioritizing, and linking natural lands in Virginia. This work was guided initially by ecological assessments conducted for other states and regions, most notably the Maryland Green Infrastructure Assessment and the Chesapeake Bay Resource Lands Assessment. Using land cover data derived from satellite imagery, the VANLA identifies unfragmented ecological units called cores, large patches of one or more natural land covers with at least 100 acres of interior cover. Interior cover begins 100 meters inward from the patch edge. Large, medium, and small cores have been identified and mapped as well as a smaller feature type called habitat fragments that may be important in the more urban localities. Cores provide habitat for a wide range of species, from species dependent upon interior forests to generalist species that utilize many different ecological communities including ecotones. Since marsh, dune, and beach land covers were included in this analysis, cores also provide habitat for species that utilize these habitats. In addition to wildlife and plant habitats, cores also provide the open space, recreation, and ecological-service benefits mentioned previously.

Cores have been mapped for the entire study area, which includes the commonwealth of Virginia and a 20-mile buffer around the state, and more than 45 prioritization attributes have been added to the cores layer. These attributes can be used by planners either on an attribute by attribute basis or to develop models combining several attributes in efforts to identify those cores that have the characteristics and provide the benefits of greatest interest to them. DCR-DNH also plans to develop an ecological composite model that will use the principle ecological parameters to develop a single prioritization attribute for ecological significance.

Still ahead for the statewide analysis are the development of Natural Landscape Blocks that buffer and support Cores and development of a network of Landscape Corridors and Nodes that connect the highest priority Cores. VANLA products, and other products of the VCLNA, are intended to be used by the Virginia Land Conservation Foundation, state and federal agencies, land trusts, and other conservation partners for land and resource conservation and habitat restoration. These products also will be made available to localities for use in local and regional planning efforts.

METHODOLOGY

Study Area

The study area includes the entire commonwealth of Virginia and a 20-mile buffer around the state. This large buffer was selected to prevent truncation of cores and corridors that cross the state boundary and to facilitate edge matching to similar projects conducted in adjacent states.

Land Cover

The Virginia Department of Conservation and Recreation contracted with the University of Maryland to develop a land cover layer for the entire state from Landsat Thematic Mapper satellite imagery. The final product, named RESAC 2000, was derived from imagery dating from 1999 to 2001. RESAC 2000 has 21 classes, nine of which represent natural land covers: Barren, Deciduous Forests, Evergreen Forests, Mixed forests, Deciduous Wooded Wetlands, Evergreen Wooded Wetlands, Emergent Herbaceous Wetlands, Mixed Wetlands, and Natural Grass. An overall thematic accuracy of 90% was reported for this layer. The resolution of this layer is 30-meters, square (University of Maryland Regional Earth Science Applications Center (RESAC). 2000).

The RESAC 2000 layer had only a very small buffer around the state, ergo additional imagery had to be acquired for coverage of the entire study area. Imagery from the Chesapeake Bay Resource Lands Assessment (also developed by UMD), National Land Cover Data (NLCD) 2001, and one piece of NLCD 1992 were merged to RESAC 2000. The NLCD classifications had to be cross-walked to match RESAC 2000 and all images had to be projected to Lambert Conformal Conic before merging.

Despite the high reported accuracy of RESAC 2000, there were several important classification errors that needed to be corrected. An accuracy assessment conducted by the VANLA analyst utilizing a five-percent random sample of the Natural Grass class revealed that it almost always represented hayfield or pasture, therefore this class was reclassified to agriculture. There were also maritime grass communities and marshes that were misclassified as agriculture. The marshes were corrected using National Wetlands Inventory (NWI) data, after excluding modified and farmed wetlands, and the maritime grasses were reclassified to a new class of the same name using high-resolution photography to confirm the occurrences were not agriculture. Beaches and dune areas were lumped into the Barren class of RESAC 2000. In order to extract these important natural land covers, undeveloped beaches and dunes were digitized from high-resolution aerial photography dated 2002 (Virginia Base Mapping Program) and the resulting polygons were used to reclassify these areas to a new class named Undeveloped Beaches/Dunes. The resulting layer is known as VANLA Land Cover.

Cores Development

The VANLA Land Cover was used to develop the VANLA cores, which are defined for this analysis as patches of natural cover containing at least 100 acres of interior cover. Interior cover begins 100 meters inward from the patch edge. This 100-meters buffer constitutes the abiotic transition zone following the “three-tree-height” rule (Harris 1984), since fully mature forests in Virginia reach maximum height around 33 meters. Harris (1984) also talks about a threshold thickness of being more on the order of six tree heights, but an abiotic transition zone of this width was considered too restrictive for areas of Virginia that are already overly fragmented. This problem of insufficient buffer thickness for some species can be handled with the Depth of Interior prioritization attribute that will be discussed later.

The first step in the core development process was to assemble a fragmentation layer that included spatial data for powerlines, pipelines, railroads, and roads. This layer was used to fragment the VANLA Land Cover, thus making a better approximation of the fragmentation in the landscape. This was necessary because these linear types of fragmentation could be hidden in areas that appeared as unbroken forests in the land cover when in reality the forest canopy obscured the fragmentation features below. Anthropogenic land covers were excluded from the analysis at this point by extracting from the fragmented land cover layer only the following classes and then classifying them as natural cover: Deciduous Forests, Evergreen Forests, Mixed forests, Deciduous Wooded Wetlands, Evergreen Wooded Wetlands, Emergent Herbaceous Wetlands, Mixed Wetlands, Undeveloped Beaches/Dunes, Maritime Grasses. One pixel width of near-shore open water was added back from the fragmented land cover to the natural cover layer. This was necessary to prevent narrow stretches of open water less than 60 meters across (two pixel widths) from splitting a core into two or more smaller cores. The interior areas of the patches in the natural cover layer were identified by using distance analysis to calculate the 100-meter abiotic transition zone of each patch. Interior areas greater than or equal to 10 acres were then identified; all patches not meeting this criterion were excluded from further analysis. The abiotic transition zone used to identify interior areas was added back to the remaining interior areas. These patches were then classified into Large Cores if they had at least 10,000 acres of interior cover, Medium Cores if they had 1,000 to 9,999 acres of interior cover, Small Cores if they had 100 to 999 acres of interior cover, and Habitat Fragments if they had 10 to 99 acres of interior cover. The Habitat Fragments feature type resulted from a pilot study for the VANLA completed in 2004 (Weber & Carter-Lovejoy) which revealed that the 100-meters minimum interior size for cores was too restrictive for some localities with more urban land cover. These features may contain natural heritage resources and have utility for recreation, open space, and storm water management, but they are too small or narrow to provide many of the other benefits of cores.

Cores Prioritization Attributes

As of the drafting of this manuscript, analyses were performed to add at least 45 prioritization attributes to the cores and habitat fragments layer. Definitions and justifications for each of these prioritization attributes can be found in Appendix A. These attributes can be categorized under the general headings of rare species and habitats, species diversity surrogates, core characteristics and context, and water quality. The prioritization attributes can be used by planners either on an attribute by attribute basis or to develop models combining several attributes in efforts to identify those cores that have the characteristics and provide the benefits of greatest interest to them. DCR-DNH also plans to develop an ecological composite model that will use the principle ecological parameters to develop a single prioritization attribute for ecological significance.

RESULTS

The results of the VANLA are the GIS data, hardcopy maps, digital maps, and this report. The GIS data include the Cores and Habitat Fragments shapefile that has been attributed with more than 45 prioritization themes. Hardcopy maps have been produced for the coastal zone portion of the VANLA and digital versions of each have been generated.

DISCUSSION

There are a number of potential uses for the VANLA. It can be used to identify targets for protection activities such as conservation land purchase or easements, for guidance in comprehensive planning efforts by localities, for review of proposed projects for potential impacts to cores and corridors, to guide private property owners and public and private land managers in making decisions that enhance ecological values, to inform the citizenry about the patterns and extent of landscape fragmentation, and to target lands for habitat restoration. Cores and Landscape Corridors can be protected for multiple benefits including open space, wildlife habitat, scenic view sheds, recreation, and the other benefits listed in the Introduction.

Since the products of the VANLA range from paper maps to GIS data, they are available to a wide range of end users. There will be those who use only the paper maps in their work, but these users need to be careful not to use maps that have become outdated. Use of the GIS data is preferred greatly because of its currentness and flexibility. End users can simply incorporate the VANLA data layers into their own GIS to compare it to their own data. End users can choose instead to use the customized ArcGIS documents (ArcMap and ArcReader) provided as products of the VANLA. The ArcGIS documents contain customized symbology in layer files that can be used for quick display of the different prioritization themes. The identify tool can be used to view the prioritization attributes of specific cores. Complex queries of the attribute table can be performed to select subsets of cores with the desired combinations of attributes. End users can develop decision tree analyses for these queries so that their methods of selection will be documented and repeatable. Finally, the prioritization attributes can be used as variables in models to generate customized prioritization scores to help identify cores with the best combinations of attributes that will help end users achieve their goals.
The prioritization parameters used in the VANLA were limited to statewide datasets. The VANLA is a landscape-scale analysis that should be refined using local data to develop solutions that make more sense at local scales.

The process of connecting cores with linear strips of natural land does not ensure that those strips will function as a Landscape Corridors. Corridors that are too narrow may consist entirely of edge and likely would not be used by interior and other sensitive species. Species attempting to use narrow corridors would be more susceptible to predation, harassment, and other edge effects mentioned previously. In order to function properly, Landscape Corridors must be sufficiently wide to provide their many potential benefits, including biodiversity conservation and species abundance (Damschen et al. 2006, Tewksbury et al. 2002, Lindenmayer & Franklin 2002). It is recommended that corridors be no narrower than 300 meters, which provides interior habitat conditions along the entire length and 100 meters of buffer on each side. Corridors should be enhanced wherever possible with the addition of Nodes of natural cover that the corridors intersect. By providing interior cover along the entire length of corridors, along with nodes of natural cover, corridors are made more attractive to interior and sensitive species. Also, by having corridors that are wide enough to provide habitat ranging from interior to edge, conditions are created that are suitable to a wider range of species than possible with narrow corridors.

Cores and Landscape Corridors are the VANLA features that should be targeted first for conservation. Once these features are protected, NLBs can be targeted next to buffer and support the core and corridor network. Habitat Fragments should be targeted only if they are coincident with high-priority resources or serve a localized need.

FUTURE APPLICATIONS

Natural Landscape Blocks Development

As of the drafting of this manuscript, Natural Landscape Blocks (NLB) had not yet been developed for the VANLA study area. NLBs were identified, however, for the VANLA pilot study covering the coastal zone of Virginia (Weber & Carter-Lovejoy 2004). The NLB methods described here result from the pilot study but are expected to be similar to those for the VANLA.

NLBs are natural areas containing one or more core areas that are bounded by major roads and unsuitable land cover greater than 100 meters across. They were developed using natural land covers from the land cover layer and eliminating areas of detected and estimated human disturbance (e.g. roads, residential areas, and other developed lands). The process involved buffering each patch in the natural land cover layer by 50 meters, thereby closing any 100 meter gaps, and then eliminating from the resulting layer any areas of coincidence with major roads, buffered developed lands derived from NLCD 2001, buffered high-density road areas developed from a focal sum analysis of the VDOT roads layer, and buffered road intersections and terminuses developed from the VDOT roads layer. The interior areas of the resulting patches were identified and then only those interior areas that intersected cores were retained. The 100-meters edge transitions were added back in and “donut holes” less than 100 acres were patched to produce the final NLBs.

Landscape Corridors Development

As of the drafting of this manuscript, Landscape Corridors had not yet been developed for the VANLA study area. Landscape Corridors were developed, however, for the VANLA pilot study covering the coastal zone of Virginia (Weber & Carter-Lovejoy 2004). The Landscape Corridors methods described here result from the pilot study but are expected to be similar to those for the VANLA.

Landscape Corridors are strips of natural cover that traverse the matrix of largely anthropogenic land covers to connect cores to each other. Corridor development required least-cost-path analysis to identify the best corridor routes. The first step in the process was to generate a corridor suitability layer that was produced by using a model to combine various landscape parameters, including land cover, urban proximity, riparian forest, roads, slope, core priority, interior forest, and offshore water. The suitability layer represents impedances, the degree to which landscape features inhibit wildlife use and movement. The resulting layer was used to create a cost-distance layer representing the least-cost-paths between cores. The lowest cost is achieved by traveling the shortest distance through the most suitable land covers and by avoiding harsh land covers like urban and suburban developments. The least-cost-paths identified the centers of each corridor. Corridors were further widened where they intersected lower-ranked cores, interior forests, and wetlands. These areas are called Nodes and they serve as patches of habitat along the corridor routes.

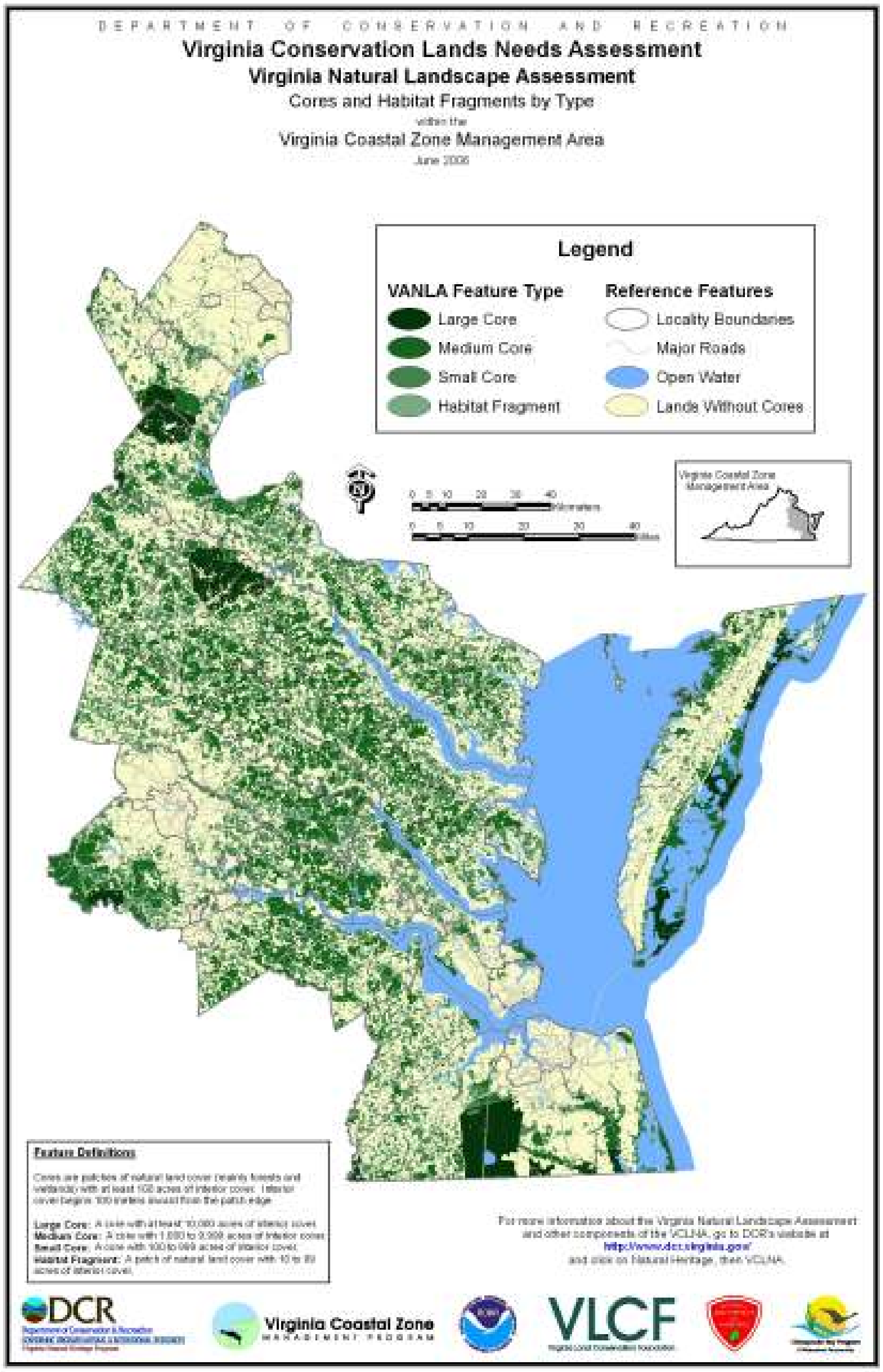


Figure 1. Coastal Zone VANLA Cores and Habitat Fragments by Feature Type.

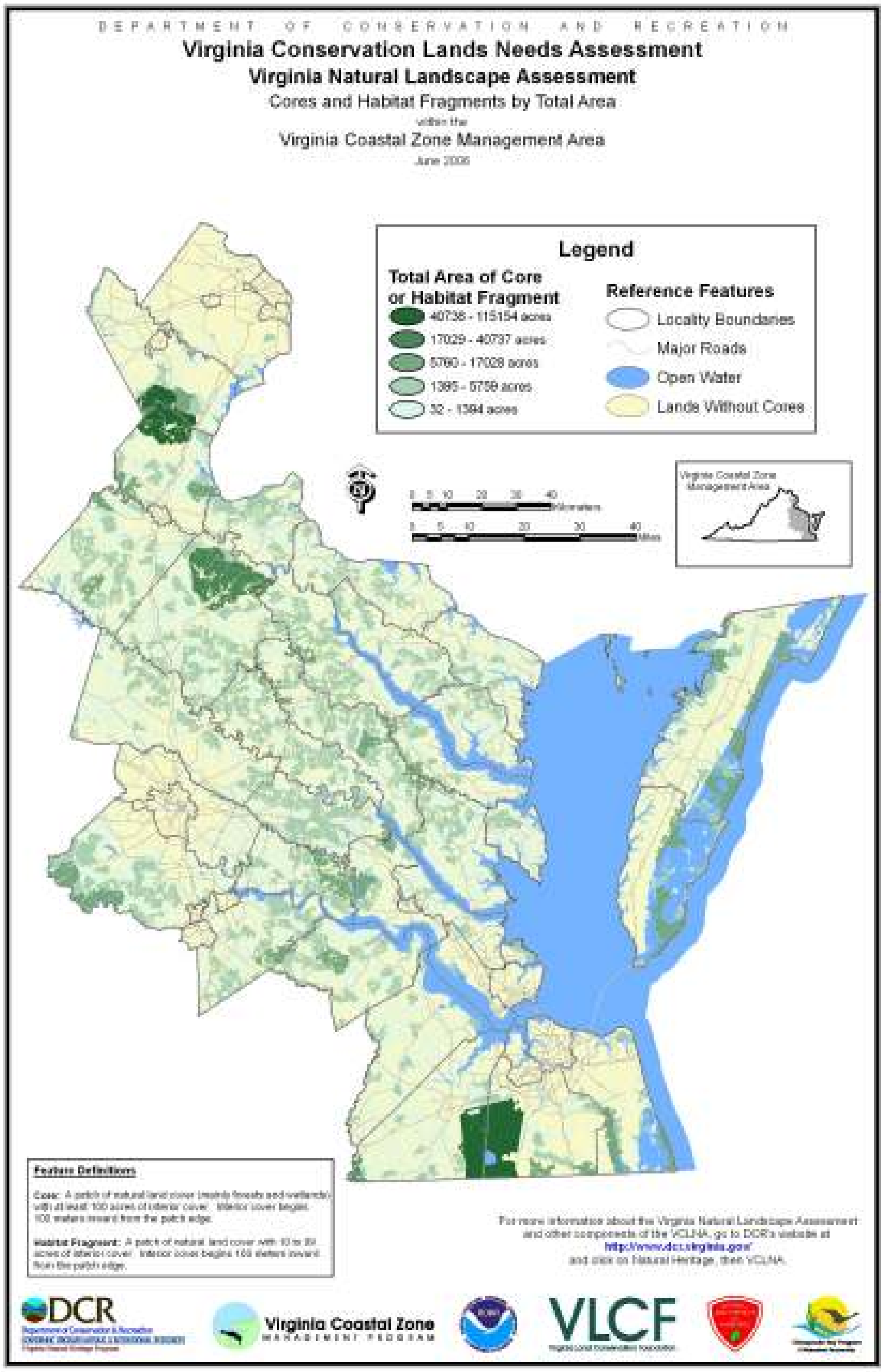


Figure 2. Coastal Zone VANLA Cores and Habitat Fragments by Total Area.

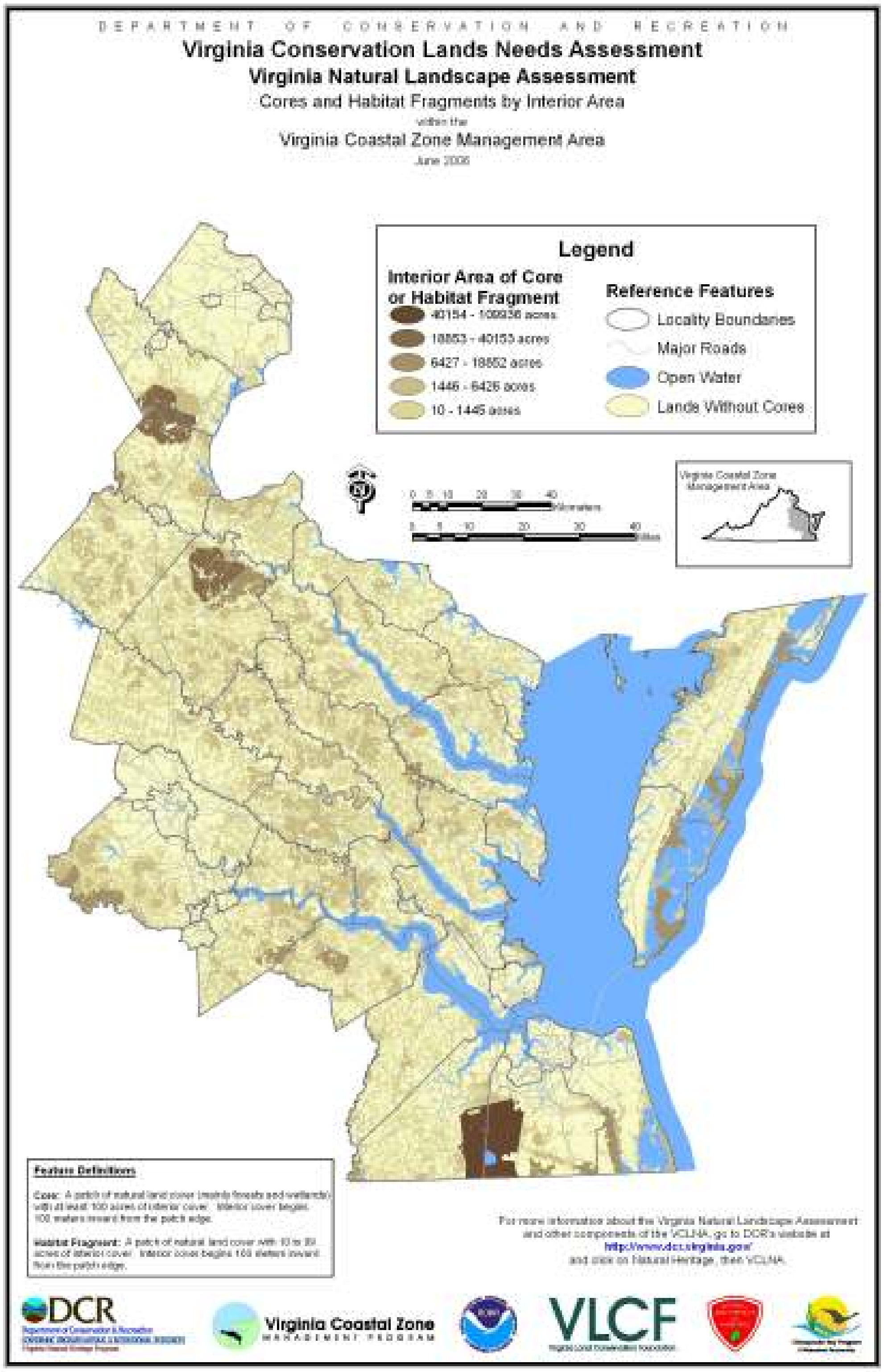


Figure 3. Coastal Zone VANLA Cores and Habitat Fragments by Interior Area.

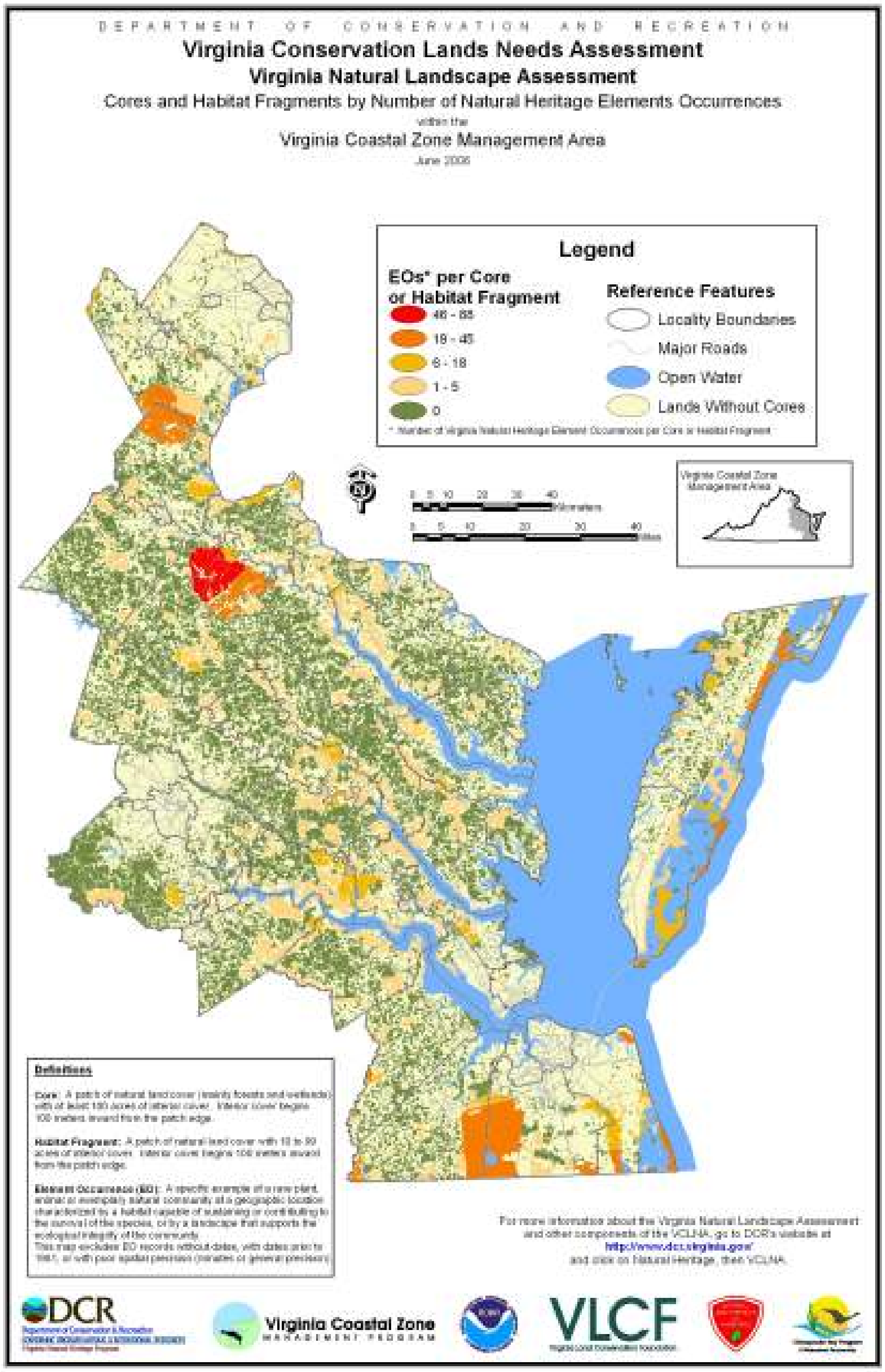


Figure 4. Coastal Zone VANLA Cores and Habitat Fragments by NH Element Occurrences.

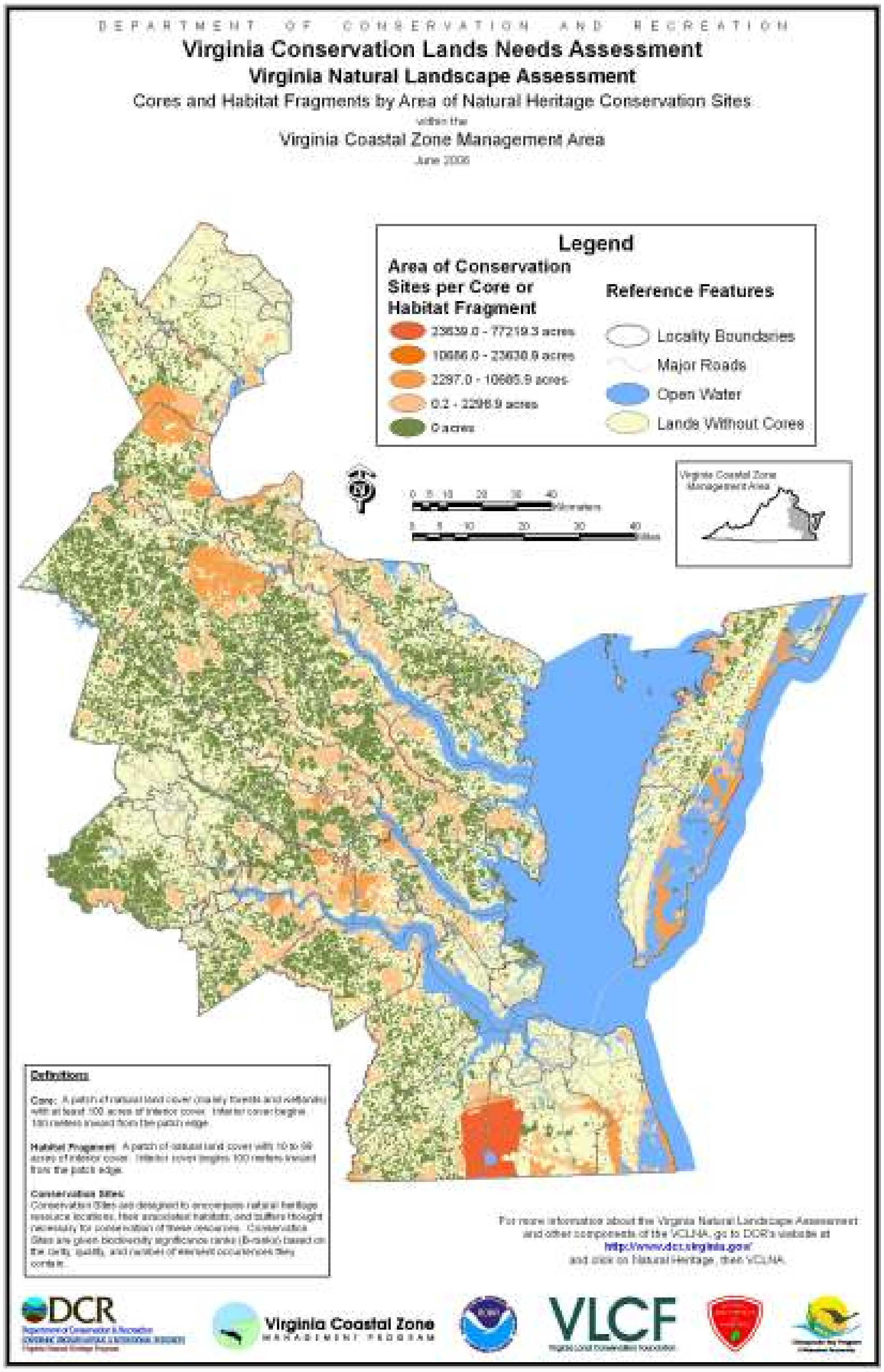


Figure 5. Coastal Zone VANLA Cores and Habitat Fragments by Area of NH Conservation Sites.

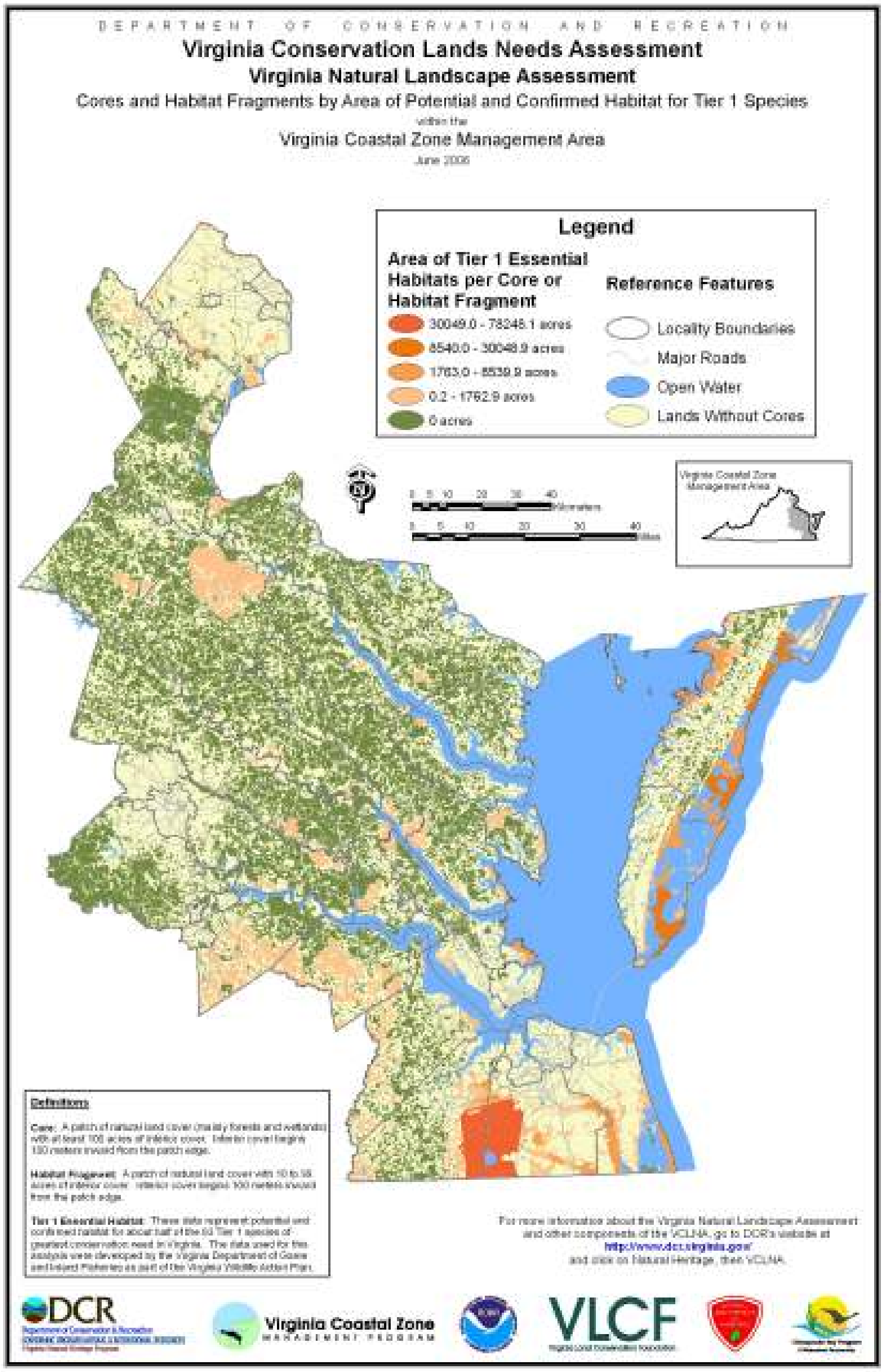


Figure 6. Coastal Zone VANLA Cores and Habitat Fragments by Area of Tier 1 Essential Habitats.

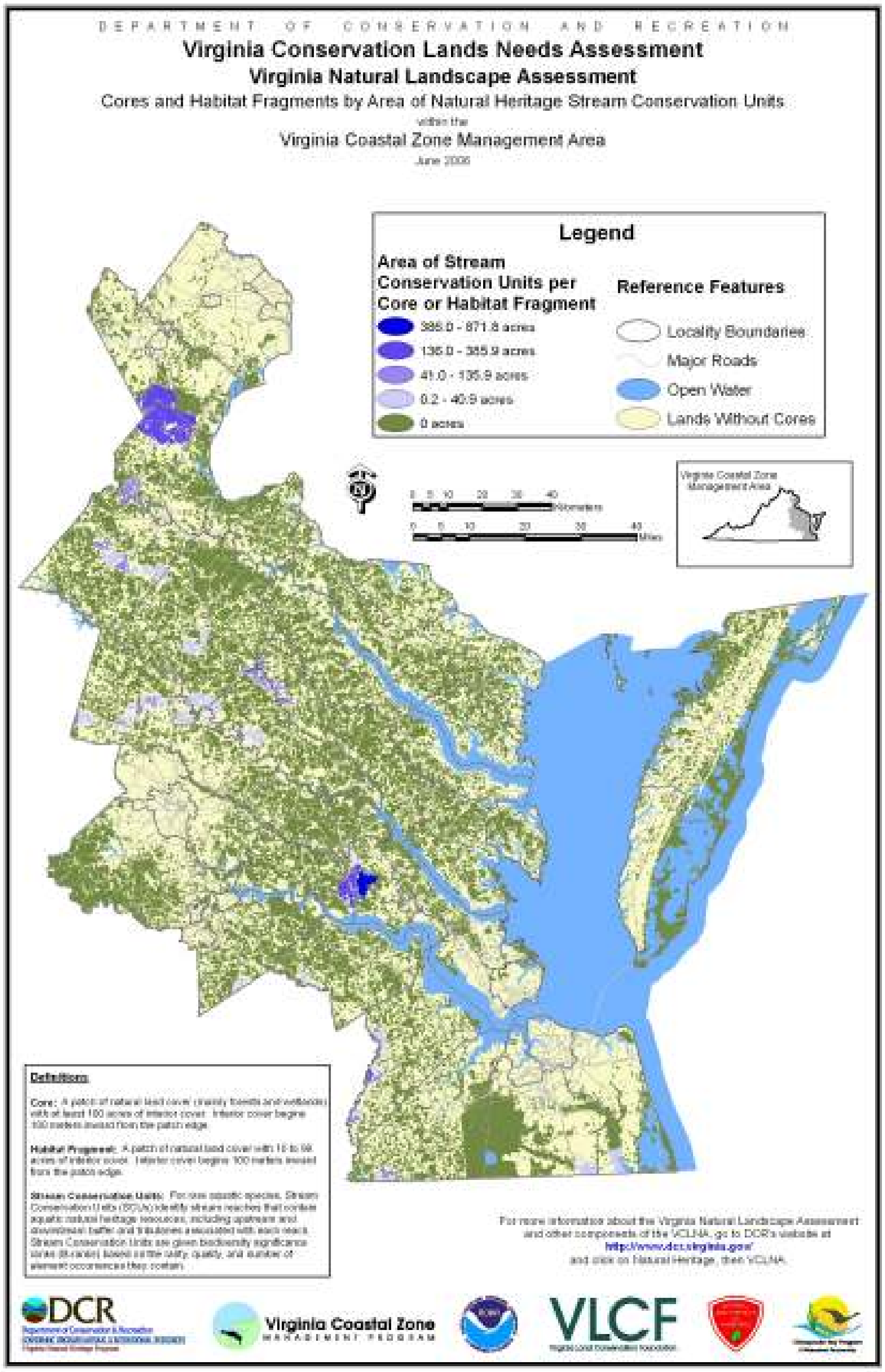


Figure 7. Coastal Zone VANLA Cores and Habitat Fragments by Area of NH Stream Conservation Units.

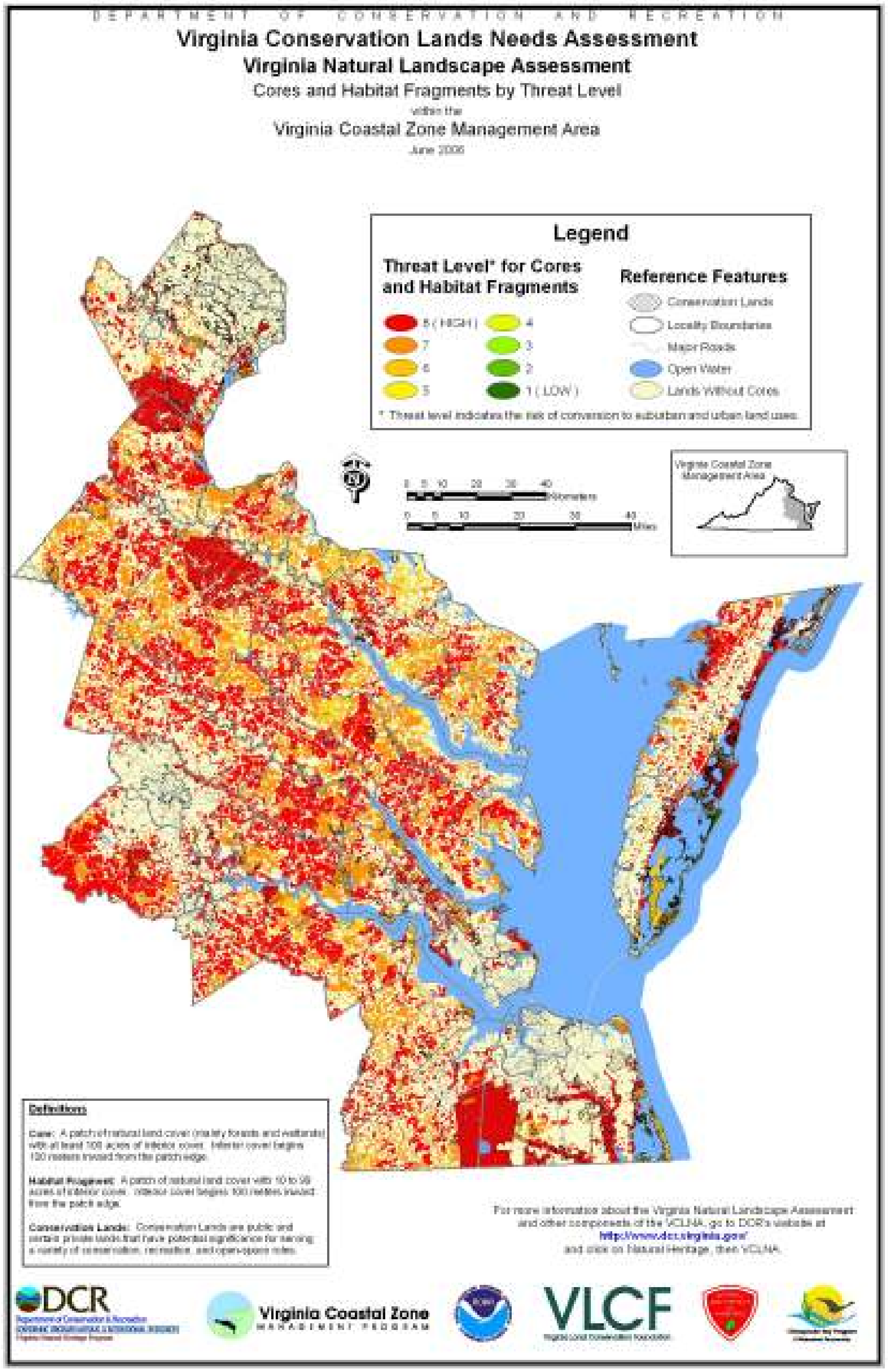


Figure 8. Coastal Zone VANLA Cores and Habitat Fragments by Threat Level.

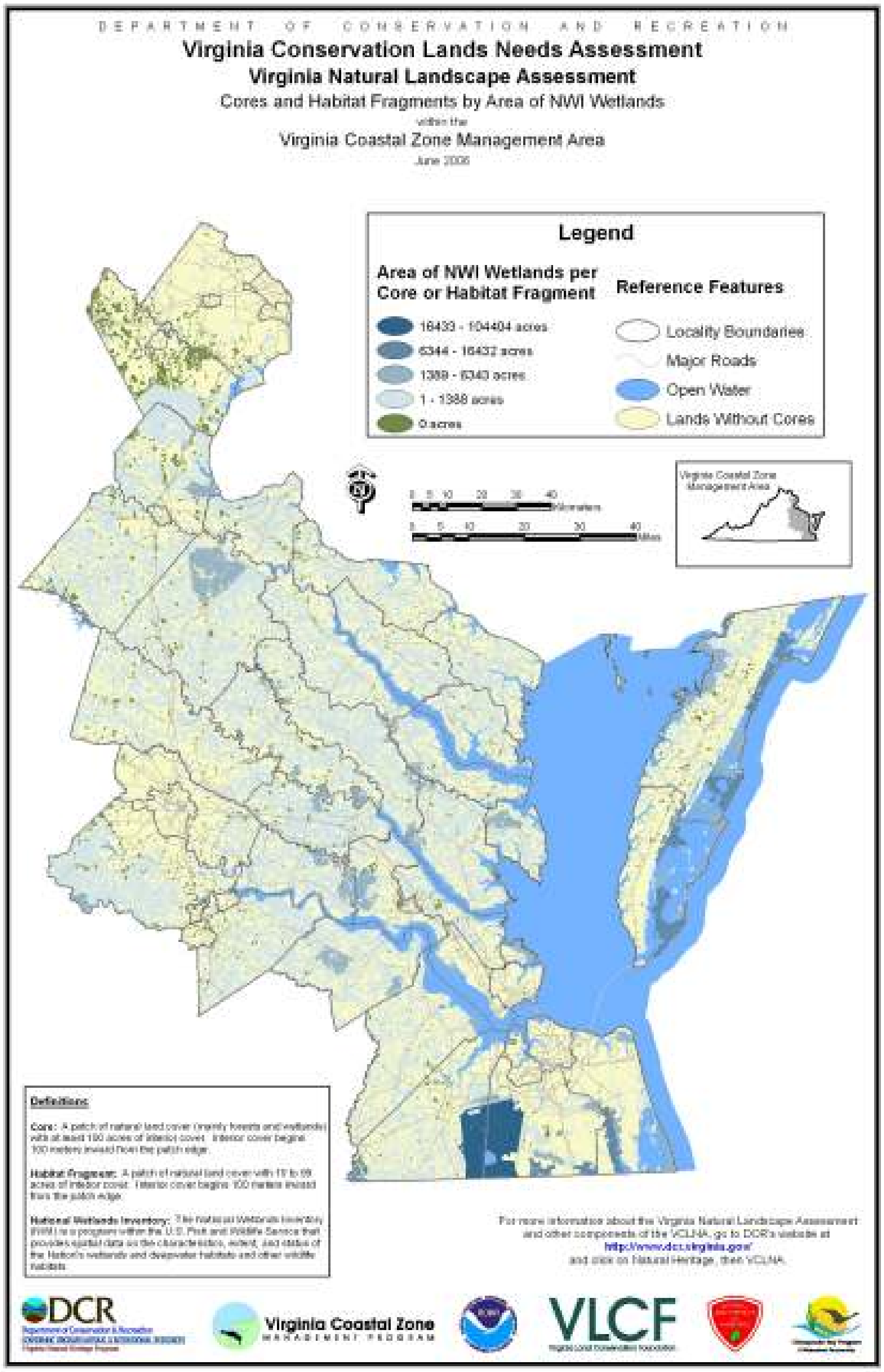


Figure 9. Coastal Zone VANLA Cores and Habitat Fragments by Area of NWI Wetlands.

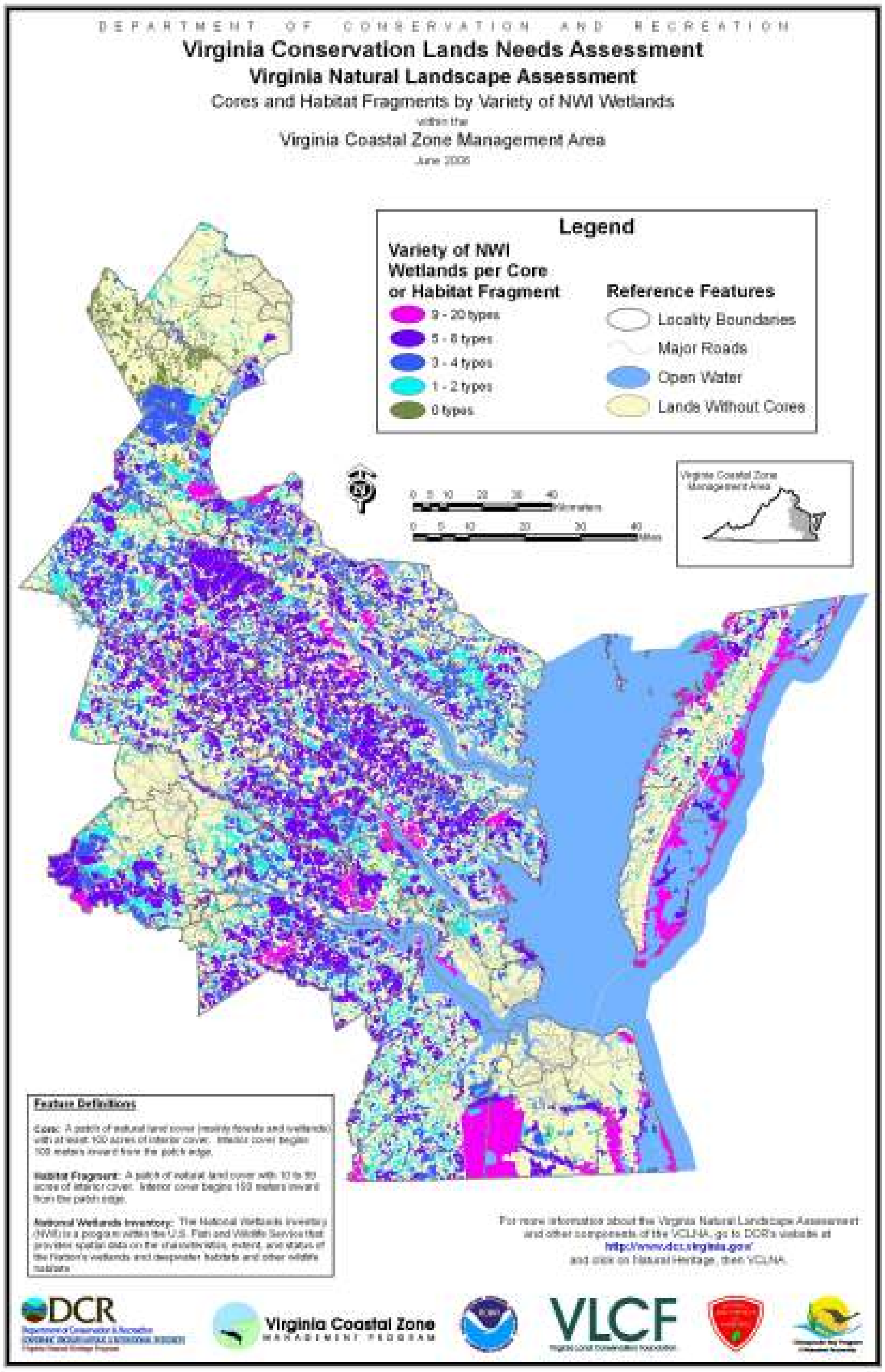


Figure 10. Coastal Zone VANLA Cores and Habitat Fragments by Variety of NWI Wetlands.

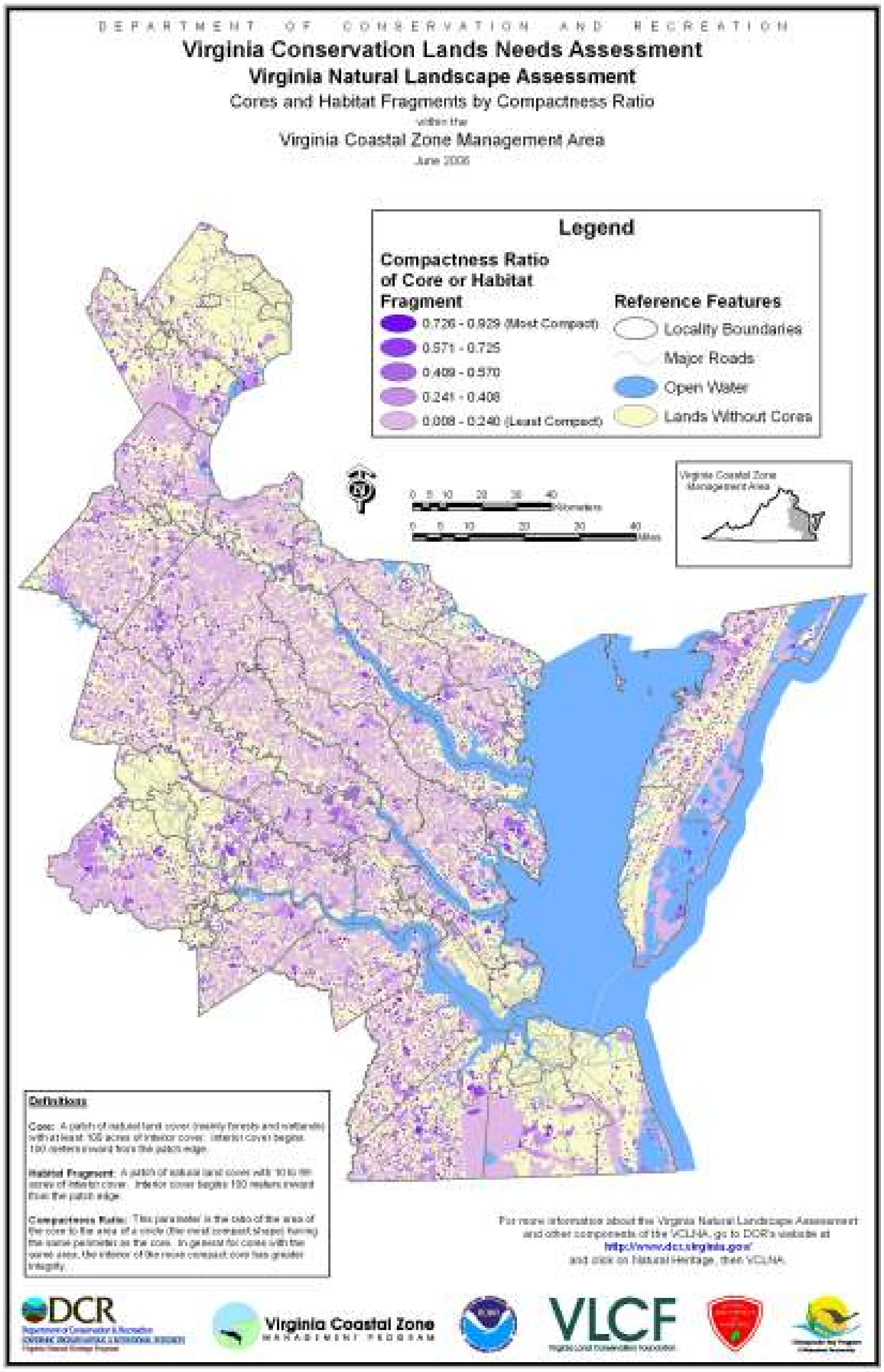


Figure 11. Coastal Zone VANLA Cores and Habitat Fragments by Compactness Ratio.

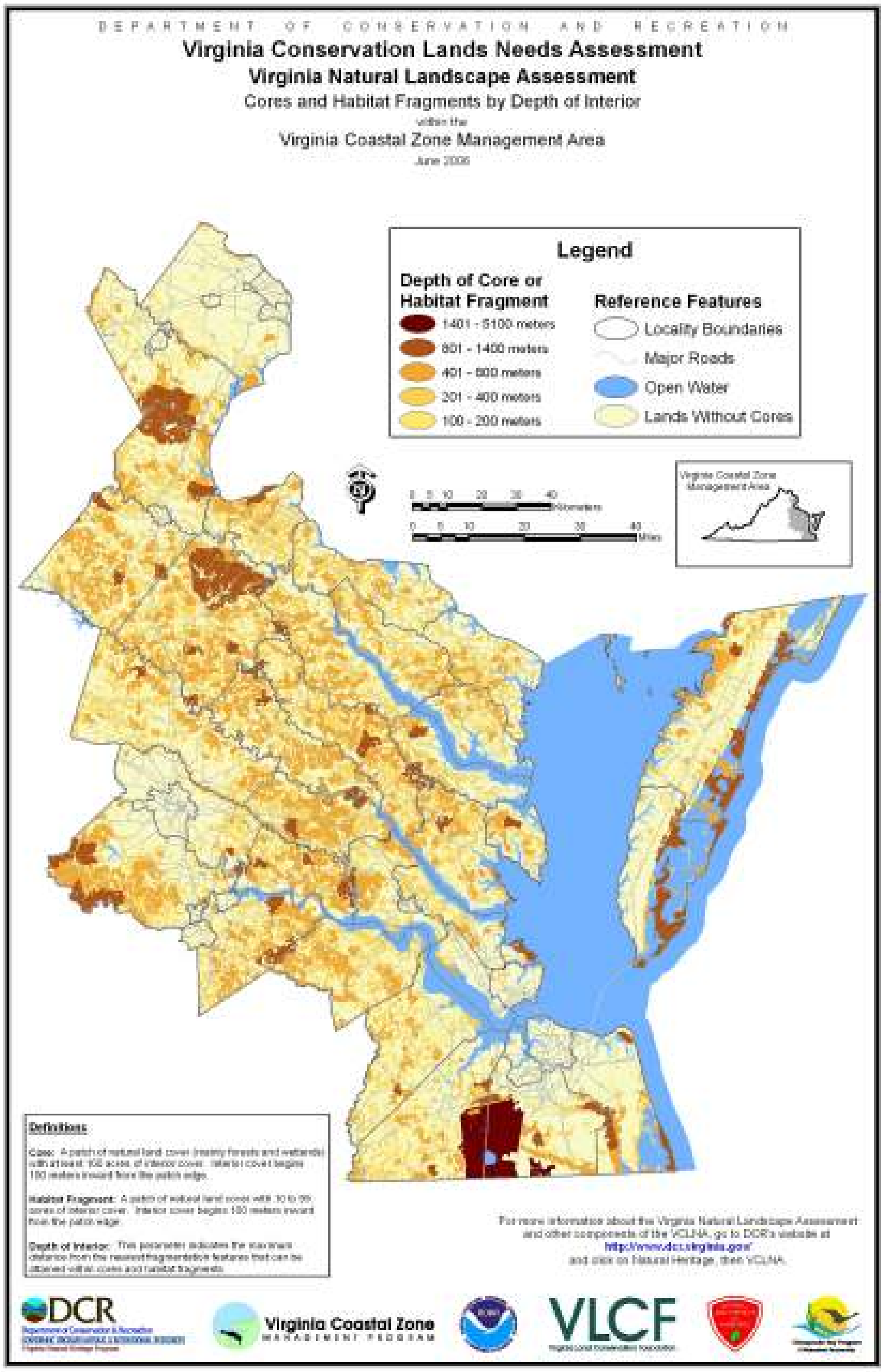


Figure 12. Coastal Zone VANLA Cores and Habitat Fragments by Depth of Interior.

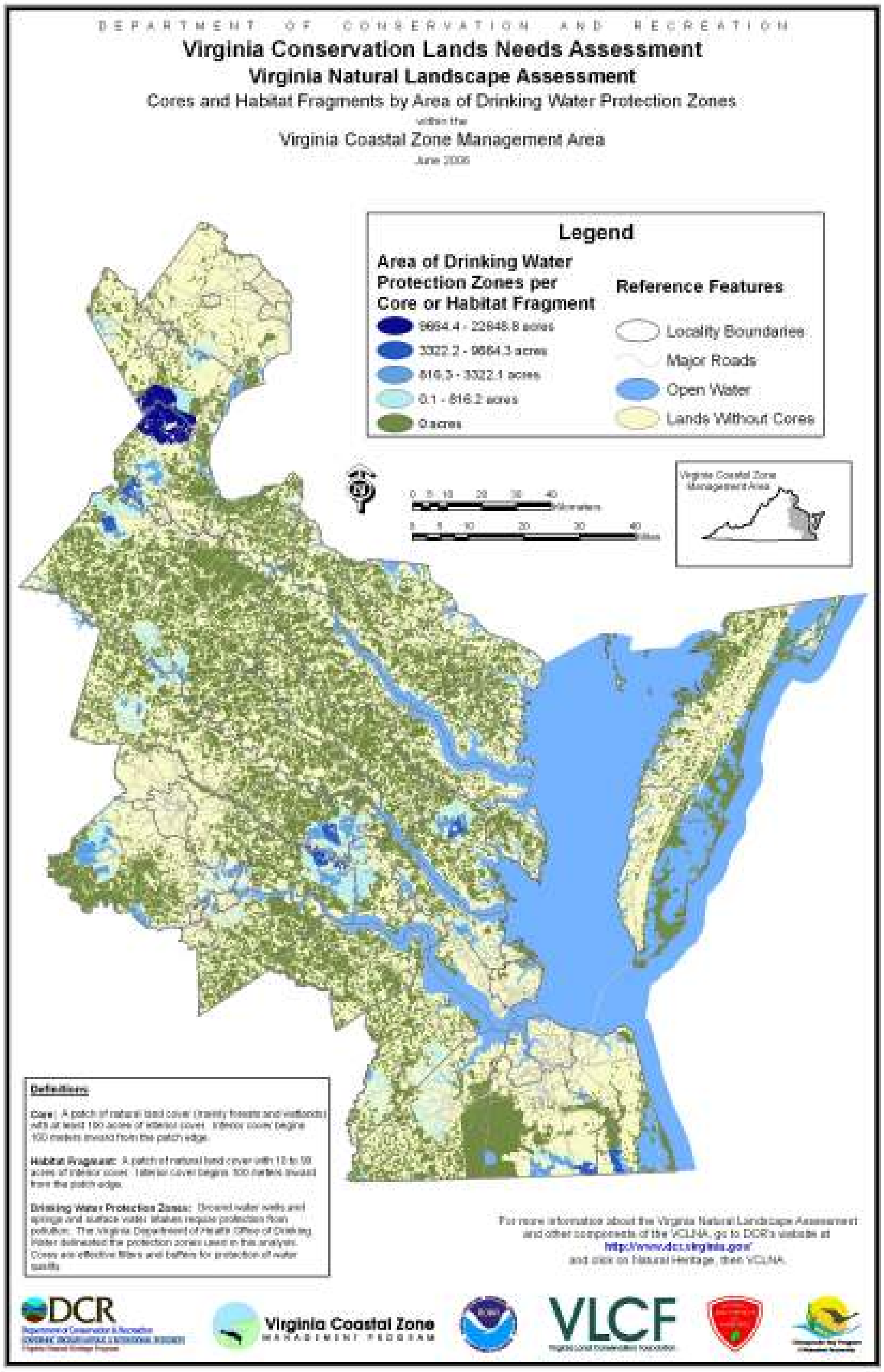
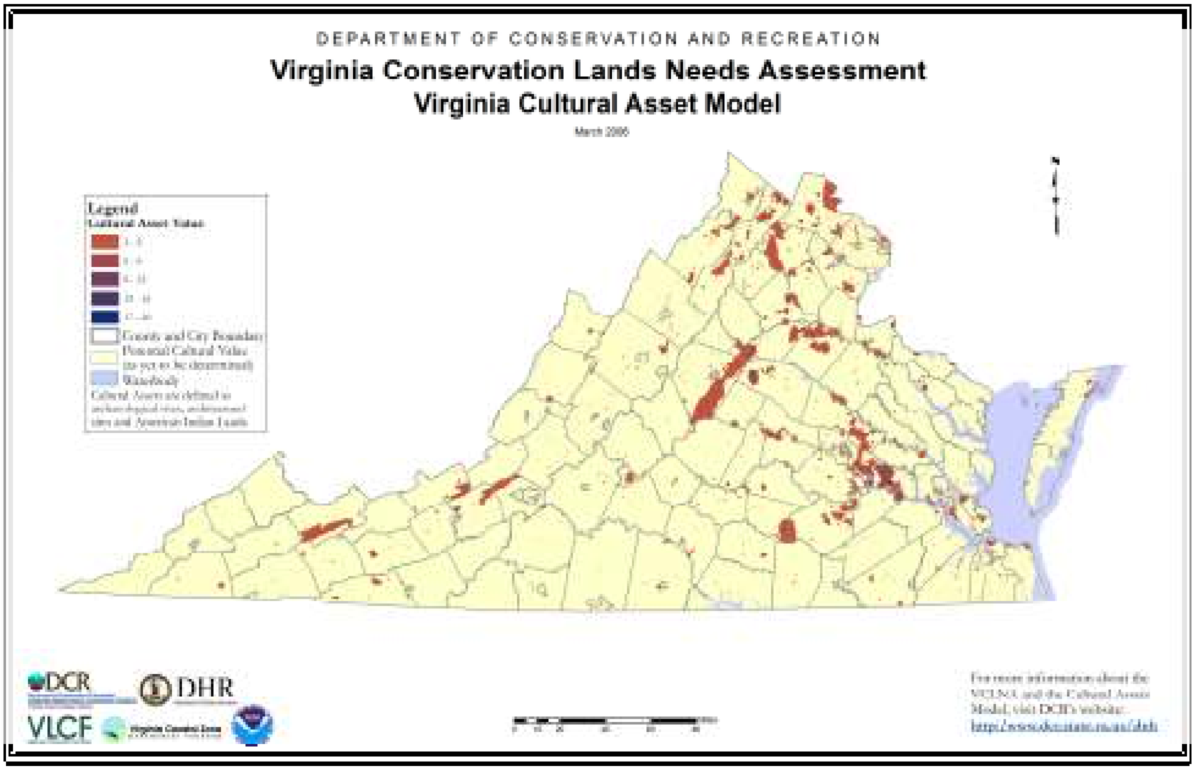


Figure 13. Coastal Zone VANLA Cores and Habitat Fragments by Area of Drinking Water Protection Zone.

Virginia Cultural Asset Model



Virginia Department of Conservation and Recreation Division of Natural Heritage
Virginia DEQ Coastal Zone Management Program
Virginia Department of Historic Resources

DHR
Department of Historic Resources

DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES
Virginia Natural Heritage Program

Virginia Coastal Zone
MANAGEMENT PROGRAM

This work is funded by the Virginia Coastal Zone Management Program at DEQ through a grant from the National Oceanic and Atmospheric Administration to the Virginia Department of Conservation and Recreation's Natural Heritage Program.

INTRODUCTION

The Virginia Cultural Asset Model was developed in an effort to map the existing (and potential) culturally valuable lands in Virginia as defined by the presence of Historic Resources and / or American Indian Lands. As development pressure continues across the state, remaining resources are being irretrievably lost to development. The development of a GIS model to delineate where culturally valuable lands exist may serve as a guide to local government, consultants, and developers as to the location of culturally rich areas in Virginia. The model also serves as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/dnh/vclna.htm.

The Virginia Department of Conservation and Recreation Division of Natural Heritage (DCR –DNH) developed the Virginia Cultural Asset Model based on the Chesapeake Bay Programs Resource Lands Assessment. DCR – DNH collaborated with the Virginia Department of Historic Resources (http://www.dhr.virginia.gov) in the development in an effort to promote the mission of DHR "to foster, encourage, and support the stewardship of Virginia's significant historic, architectural, archaeological, and cultural resources". DHR was used as the expert source for model parameter weighting and as the data sources. For information, or to request archaeological or architectural data, please contact the Virginia Department of Historic Resources.

The statewide Virginia cultural model includes the following datasets with the associated attribute that controlled the ranking:

- Archaeological and Architecture sites
  - Entity has been listed as a National Historic Landmark
  - Entity listed in the Virginia Landmarks Registry
  - Entity has been listed in the National Register of Historic Places
  - Historic preservation easement
  - Sites that are eligible to be on the national register
  - Sites for which a national register eligibility determination has not been made
  - Sites that are not eligible to be on the national register
- American Indian/Alaska Native Areas: The American Indian Areas represent federally designated area boundaries for the Mattaponi, the Pamunkey, the Chickahominey and the Eastern Chickahominey tribes. The boundaries were created by the U.S. Census Bureau and do not necessarily represent all American Indian held lands by these tribes. The U.S. Census Bureau defines these areas as:

  "These areas include the legal federally recognized American Indian reservations, off-reservation trust land, tribal subdivisions, Alaska Native Regional Corporations, and Hawaiian home lands. These areas also include the tribal designated statistical areas, Oklahoma tribal statistical areas, and Alaska

Native village statistical areas that are defined for federally recognized tribes without a legal land base. The boundaries of federally recognized American Indian and Alaska Native areas are provided by the tribal governments. The State of Hawaii Department of Hawaiian Home Lands provides the boundaries for Hawaiian home lands. The boundaries of state-recognized American Indian reservations and state designated American Indian statistical areas (for state recognized tribes without a reservation) are provided by a state liaison designated by the state's governor."

(http://factfinder.census.gov/home/aian/mso01icd.pdf)

It is important the end user realize the cultural model represents the cultural value of land in Virginia, and does not represent legal boundary delineations. The model serves to provide an overview of cultural assets throughout the Virginia landscape as defined by the absence / presence of historic and cultural resources.

The cultural_pks model includes the above datasets and Federal, State and Local Parks. Parks are included in this layer as a representation of "place attachment". Studies done on valuation of place attachment associate parks or wild lands with more than places for recreational opportunities but as places that have historically and cultural significance as well as psychological meaning, "settings that possess unique qualities" (Williams 1992, Williams 1989).

The incorporation of parks as a sense of place value has application as planners are often "outside the social circles that assign meaning to a place and therefore tend to discount them" (D.R. Williams and S. I. Stewart, 1998). With "the spread of mass culture" which results in introduced land uses (i.e. strip malls, large scale cookie cutter shopping centers), outsiders are forcing their sense of place onto local residents (D.R. Williams and S. I. Stewart, 1998). The inclusion of parks in one of the models represents place value for local residents as they related to their specific environment.

Application of the Cultural Model

Some general categories of uses to which the cultural model can be applied include:

- Targeting – to identify targets for protection activities
- Prioritizing – to provide primary or additional justification for key conservation land purchases and other protection activities.
- Local planning – guidance for comprehensive planning and local ordinance and zoning development.
- Assessment – to review proposed projects for potential impacts to archaeological sites, architectural sites or American Indian Lands
- Land Management – to guide property owners and public and private land managers in making land management decisions that enhance cultural values
- Public Education – to inform the citizenry about the cultural value of their community, helping retain the unique sense of place associated with these communities.

METHODOLOGY

Base Data

The Virginia Department of Historic Resources provided an historic resources geodatabase with archaeological and architectural polygon feature classes. Each feature class contains multiple attributes listed in Table 1.

Native American Areas were downloaded from the Geography Network and are Census TIGER® 2000 data.

Park polygons were used in a cultural submodel and represent a spatial delineation of Federal, State and local parks throughout Virginia. Parks data was obtained from the Department of Conservation and Recreation Division of Natural Heritage.

Methodological Steps

See Figure 1.

Historic Resources geodatabase was dated March 1, 2006 and all cartographic products are dated March 2006 to reflect the currentness of the Historic Resource geodatabase at that time. New data has been subsequently added to the Historic Resources databases and continues to be added. For the most comprehensive and up to date historic resources GIS data, contact the Virginia Department of Historic Resources (http://www.dhr.virginia.gov/homepage_features/richmond.htm).

Assigning Ranks

The Virginia Department of Historic Resources held internal meetings to discuss and develop the ranking system that was applied to the data. These ranks were based on expert knowledge of the cultural value of the datasets, individually and in relation to each other. For example, an archaeological site that is listed as a National Historic Landmark is classified as having a greater cultural value based on the definition and requirements of an entity to be placed on the National Historic Landmark list than an entity that is on the Virginia Landmarks Registry. Conserved status was not used in the development of the ranking system.

The archaeology and architectural feature classes were attributed with weight fields to carry specific numeric values for each parameters defined in the weight table. A total weight was then calculated. See Table 1. Where no values were assigned for a weight, the value was calculated as 0.

The American Indian Lands feature class was attributed with a weight field. A weight of 5 was assigned to all polygons in the feature class.

Federal, State and Local parks were reprojected to Lambert NAD 83. A weight field was added and attributed with a value of 2.

<u>*Conversion to GRIDs*</u>

Archaeology and Architecture Sites

To ensure small area polygons were captured in the conversion to grid, polygons with an area less than 700 square meters were selected and exported to a feature class called arch_lt700. The selection was reversed and the remaining polygons were exported to a feature class called arch_gt700.

The original data had stacked polygons within the same feature class, representing different entities. In order to ensure these stacked entities were summed to show the compound effect of having two cultural entities in the same place (i.e. to ensure the polygon values could be added as grids), the stacked entities had to be exported to different feature classes. Topology rules were created and validated in ArcCatalog. The rules were set as MUST NOT OVERLAP and each topological error (which acted to identify stacked polygons) was attributed with a unique ISSUE attribute. Each unique ISSUE was exported to a unique feature class.

Every feature was buffered by 15 meters with the Buffer Tool in ArcToolbox. This was done to ensure complete conversion to a grid. Some entities (i.e. roads or bridges) and were not completely converting to grid because of the entity shape. DHR and DNH felt it was appropriate to buffer by 15 meter (half a 30 meter pixel), particularly since these areas are historic or archaeological sites and a slight increase in area is not misrepresentation. No buffer would result in under representation of historic resources, which is considered to be a greater error than slight over representation. In addition, Historic Resource data is sensitive data, actual locational information could not be presented in the model.

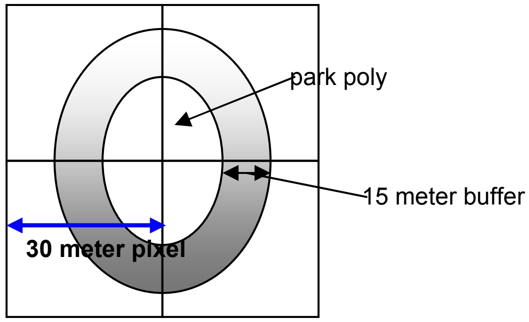
Each unique issue feature class was converted to 30 meter grids in ArcMap Spatial Analyst with the Total Weight set as the value. A visual QA/QC was done on the data to ensure complete conversion. If a polygon was found that did not convert to grid, it was selected and copied into the lt700 feature class for re-conversion (see Quality Control section).

The archaeological and architecture sites that were less than 700 square meters were converted to label centroids with X Tools. Each centroid was then buffered with a 30 meter buffer. The buffered feature class was converted to a 30 meter grid with the total weight set as the value in ArcMap Spatial Analyst (called ARCHABUFF); all NoData values were set to zero.

All the grids were summed together in ArcGRID with the final grid's values representing the total cumulative weight for archaeological and architectural assets:

Parks

The parks shapefile was converted to a grid and visually checked for missing polygons. This method was followed because the polygons that were not converted in the parks did not follow a pattern like the archaeological and architectural entities (where shape area could be used to determine polygons that would not convert to a grid). Missing polygons were put in a separate feature class called pks_reconvert. The prks_reconvert were buffered at 15 meters. The 15 meter buffer area was chosen because it is half a pixel; the additional 15 meters would not introduce new area at a significant level to inaccurately represent park land. For example:



The pks_reconvert feature class was converted to a grid and merged with the parks grid in ArcGRID.

American Indian Lands

The American Indian Areas feature class was converted to a 30 meter grid with Spatial Analyst in ArcMap with the total weight set as the value.

Final Cultural Models

All grids were added together in ArcGRID with the value field representing the total cumulative weight for a cultural asset. The Cultural grid includes archaeological, architectural and American Indian Area data. The Cultural_pks grid includes archaeological, architectural, American Indian Lands and Federal, State and local parks data.

The Cultural grid was converted to a feature class with Spatial Analyst ArcMap. The following fields were added to the feature class and attributed accordingly:

1. TOT_VALUE (short integer, numeric cumulative value of cultural asset)
2. CULT_ID (text, original DHR cultural ID)
3. ARCHT (text, Y or N indicating the absence or presence of an architectural entity)
4. ARCHT_wt (short integer, numeric cumulative value of architecture weight)
5. ARCHAE_wt (short integer, numeric cumulative value of archaeological weight)
6. ARCHAE (text, Y or N indicating the absence or presence of an archaeological entity)
7. AIND_wt (short integer, numeric cumulative value of American Indian Lands weight)
8. AIND (text, Y or N indicating the absence or presence of an American Indian Land)
9. PRKS (text, Y or N indicating the absence or presence of parks – only applicable to the cultural_pks model)
10. PRKS_wt (short integer, numeric cumulative value of a park – only applicable to the cultural_pks model)

Model Validation

The Cultural Model was quality controlled/assured through a visual assessment process. The USGS 3 ¼ minute quarter quadrangle was overlaid on top of the grid and original input data feature classes. The USGS grids were systematically assessed in ArcMap to visually check for the absence of data in the cultural grids in relation to presence of an original polygon in the original input feature classes.

This process was repeated by the Department of Historic Resources. DHR validated 20% of the total number of archaeological sites and 20% of the architectural sites. A validation with at least 95% correct indicated a validated and effective model. Validation came back at higher than 95% for correctness.

RESULTS

Maps were produced for the entire Coastal Zone and the Planning District Commissions and are included as part of the final report. The report will be available online and on CD by request and include:

- Maps showing:
    - Cultural value of land
    - Vulnerable cultural lands
    - Natural heritage sites and cores that intersect cultural lands
- A report detailing the methodology
- Metadata
- Personal geodatabase and shapefiles with cultural and cultural_pks feature classes attributed for the absence or presence of an archaeological, architectural, American Indian Land and / or park land, the associated total weight for that particular entity and the cultural total weight which is the sum of all weights of all entities present in the specific geographic location.

DISCUSSION

The Cultural Asset Model may serve as a guide to state and local government, consultants, and developers as to the location of important cultural resources. The model can be used alone or integrated with other datasets, such as the VCLNA Vulnerability Model (growth prediction model) or Ecological Model, to identify which cultural resources are most at risk to growth pressures or would serve to contribute to an ecological core area.

The model may also be used to help guide local land use planners in the development of their comprehensive plans. It is important to look at the landscape as a whole and assess how growth may impact cultural resources, the environment, what remaining farmland or timberland is available or how water quality will be affected, before more development is introduced.

The models serve as part of a larger green infrastructure plan, which aims to model where Virginia’s conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/dnh/vclna.htm.

FUTURE APPLICATIONS

Additional Data Incorporation

Development of a statewide model constrains the model to statewide available datasets. In the future, particular areas can be appended to with additional information specific to that area. One particular dataset is Civil War Battlefields where localized datasets may exist and provide valuable information to include in the existing cultural model. These data can be added to the final model grid (see Appendix *Adding Data to the Cultural Model*) to create a more comprehensive, localized Cultural Asset Model.

Prediction Model

In the state of Virginia, many areas have not been surveyed for historic resources. Future development of a prediction model to determine areas of potential cultural value can be determined through the use of GIS, correlation and regression analyses. Prediction models may incorporate datasets such as:

- Distance to water
- Soil type
- Slope
- Additional constraints

Initial prediction model development indicating correlated datasets with which to predict potential cultural sites, but further research must be conducted by the Department of Historic Resources to assess null site locations and their effect on the prediction model.

Viewshed Analysis

Areas that surround culturally valuable land may support the value of such lands through aesthetic qualities. The development of viewsheds for a particular site will provide a delineation of lands that act to support this cultural value. Viewsheds were not run for all sites in the Cultural Model due to the number of sites. Individual sites, such as Monticello, can be selected and viewshed analysis run to assess the surrounding land’s value in promoting a cultural resource such as Monticello/

Table 1. Cultural Model Attribute Ranking
1 = low weight, 2 = low to med weight, 3 = med weight, 4 = med to high weight, 5 = high weight

LAYER	**ATTRIBUTE**	**DESCRIPTION**	**RANKS**
architecture	Register = V	Entity has been listed in the VA Landmarks Registry	4
architecture	Register = N	Entity has been listed in the National Register of Historic Places	4
architecture	Register = NHL	Entity has been listed as a National Historic Landmark	5
architecture	Register = Easement	DHR holds a historic preservation easement	4
architecture	Eligibility = Y	Sites that are eligible to be on the national register	4
architecture	Eligibility = N	Sites that are not eligible to be on the national register	1
architecture	Eligibility = <null>	Sites that are potentially eligible to be on the national register	2
architecture	Eligibility = Y and N		4
architecture	Eligibility = PIF Deferred		3
architecture	Eligibility = pot or potential		3
archaeology	Eligibility = Y	Sites that are eligible to be on the national register	4
archaeology	Eligibility = N	Sites that are not eligible to be on the national register	1
archaeology	Eligibility = null	National register eligibility determination not yet made	2
archaeology	Eligibility = Y and N		4
archaeology	Eligibility = PIF Deferred		3
archaeology	Eligibility = pot or potential		3
archaeology	Register = V	Entity has been listed in the VA Landmarks Registry	4
archaeology	Register = N	Entity has been listed in the National Register of Historic Places	4
archaeology	Register = NHL	Entity has been listed as a National Historic Landmark	5
archaeology	Register = Easement	DHR holds a historic preservation easement	4
Parks		Federal, State and Local Parks	2
American Indian Lands			5

Cultural Model Methodology

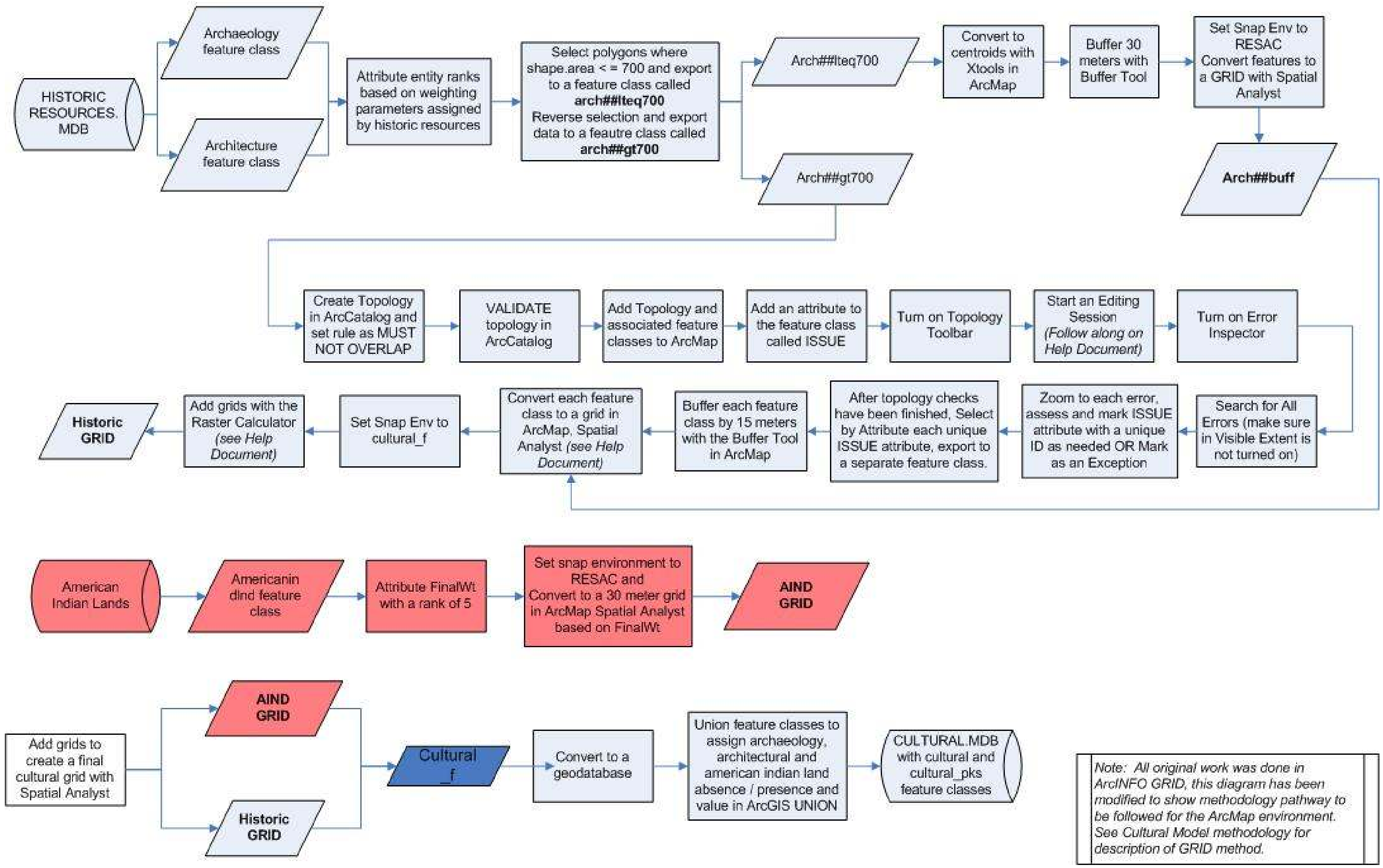


Figure 14. Methodology Overview Diagram.

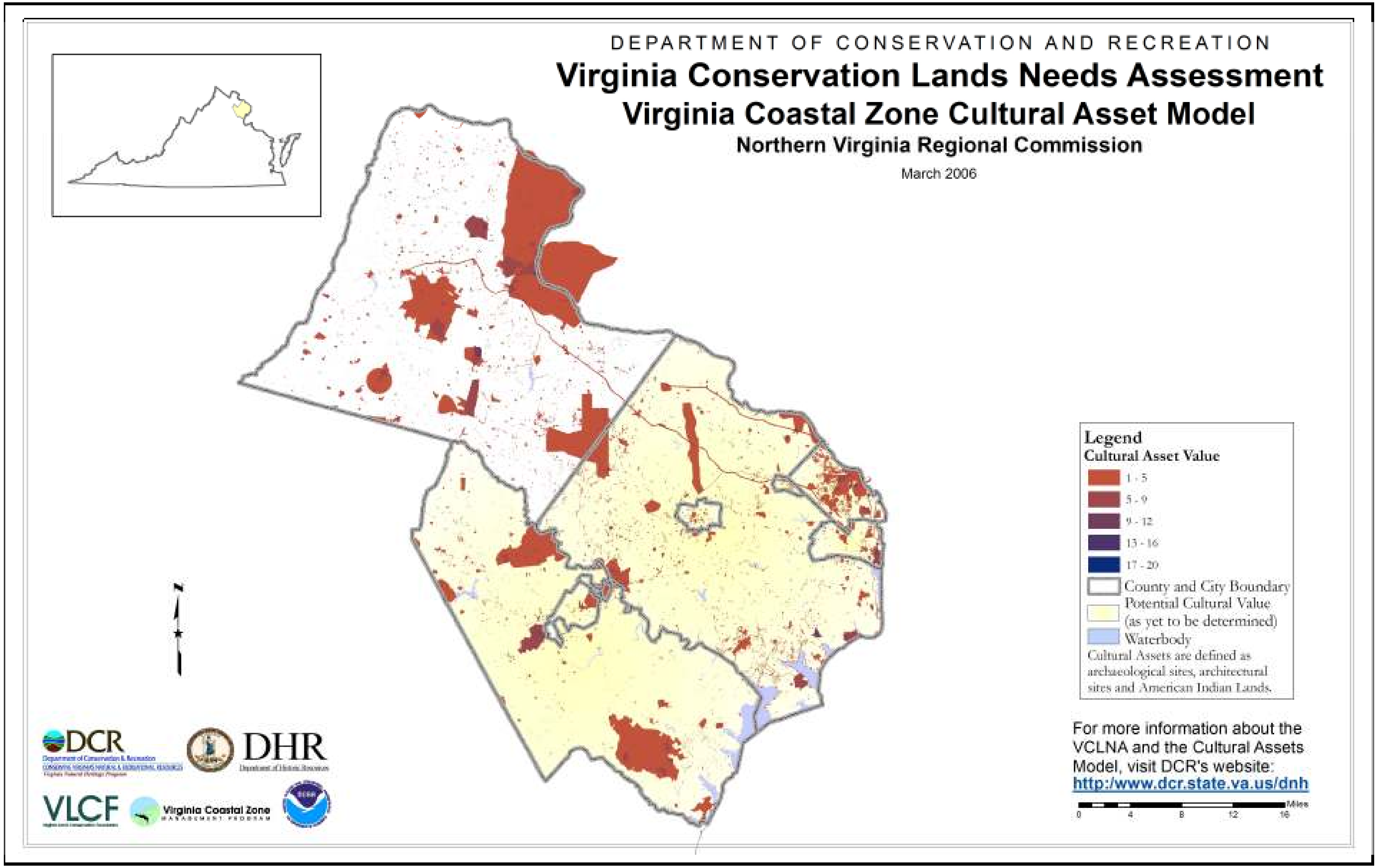


Figure 15. PDC 8 Northern Virginia Regional Commission Cultural Asset Model.

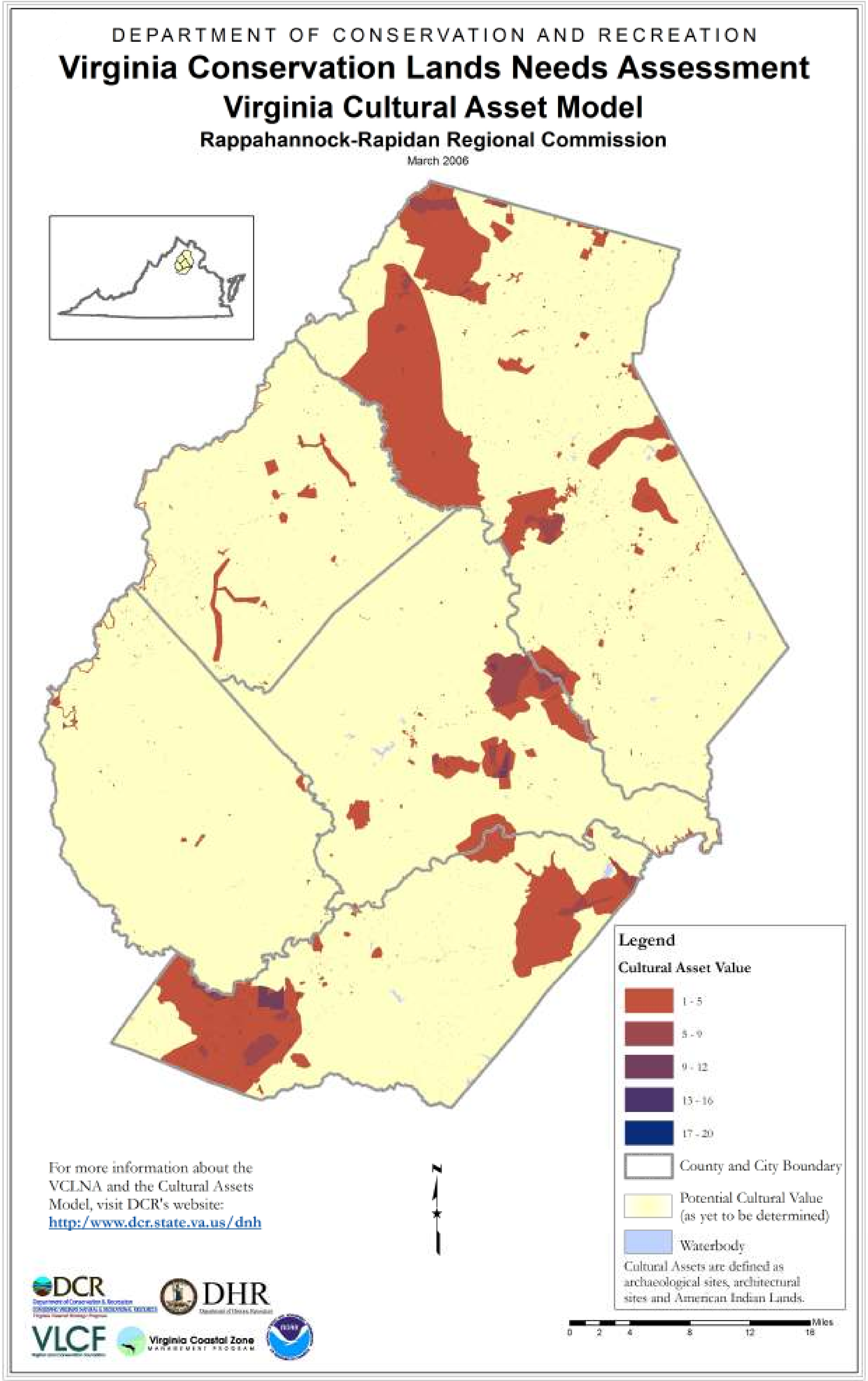


Figure 16. PDC 9 Rappahannock-Rapidan Regional Commission Cultural Asset Model.

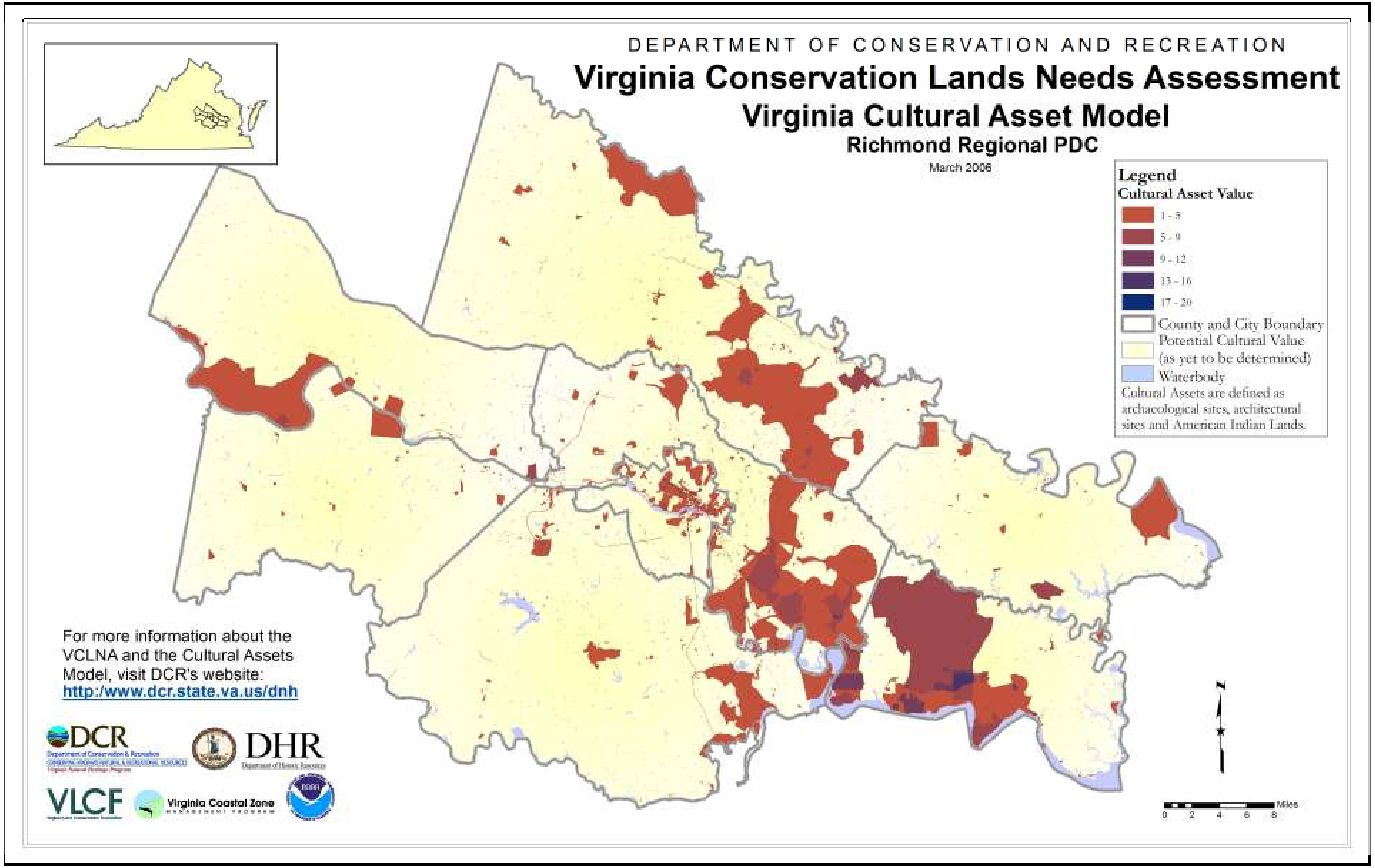


Figure 17. PDC 15 Richmond Regional PDC Cultural Asset Model.

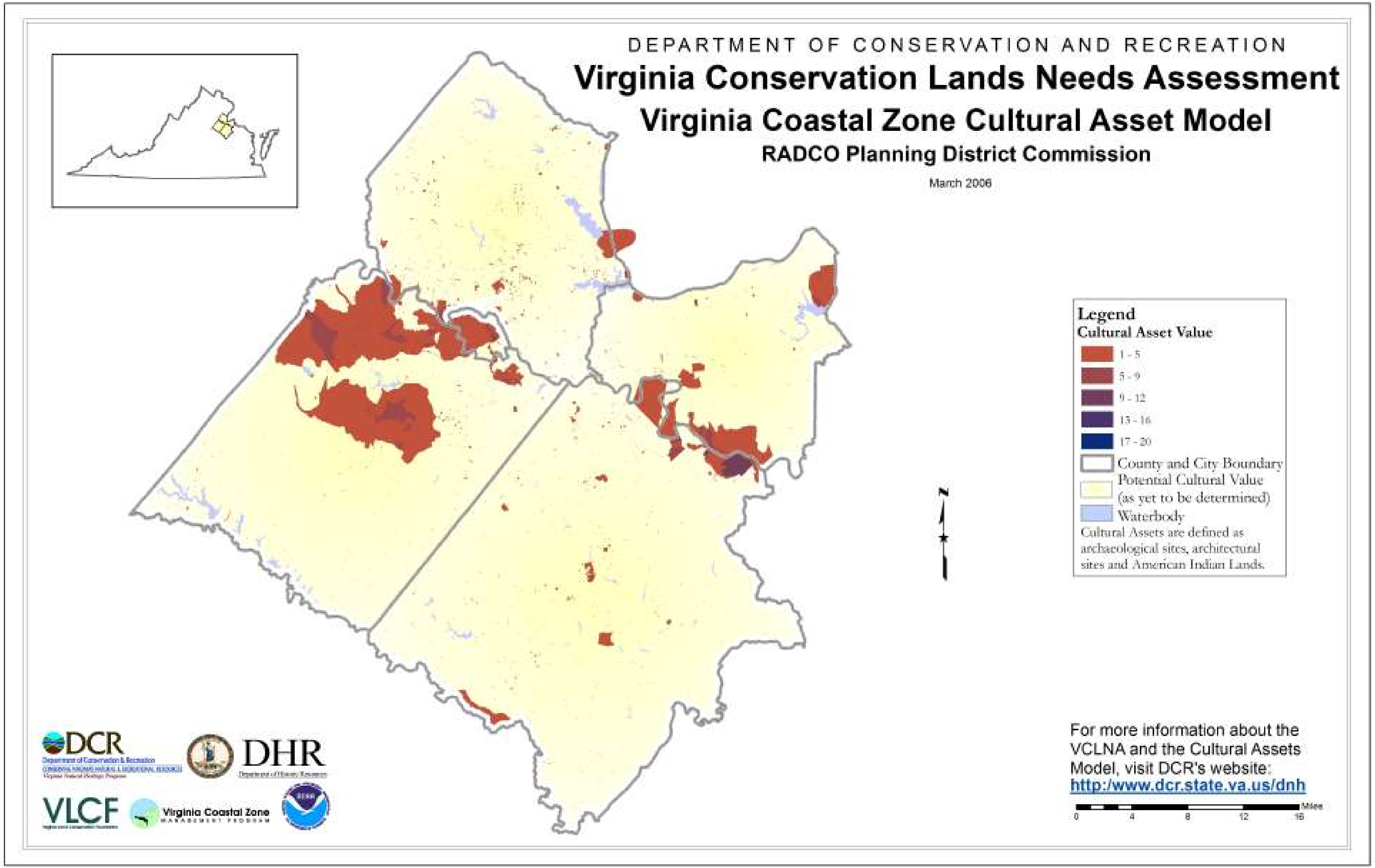


Figure 18. PDC 16 RADCO PDC Cultural Asset Model.

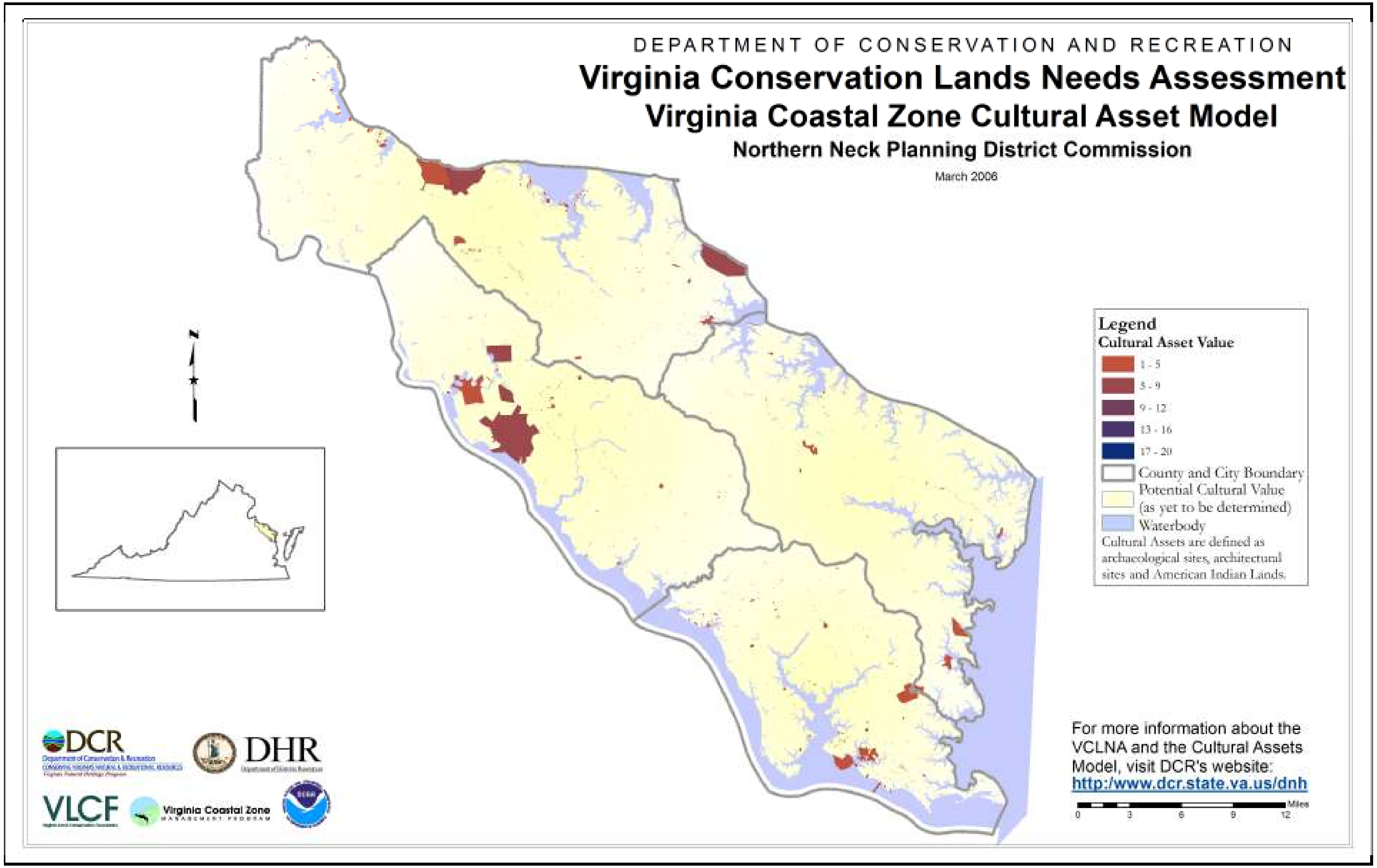


Figure 19. PDC 17 Northern Neck PDC Cultural Asset Model.

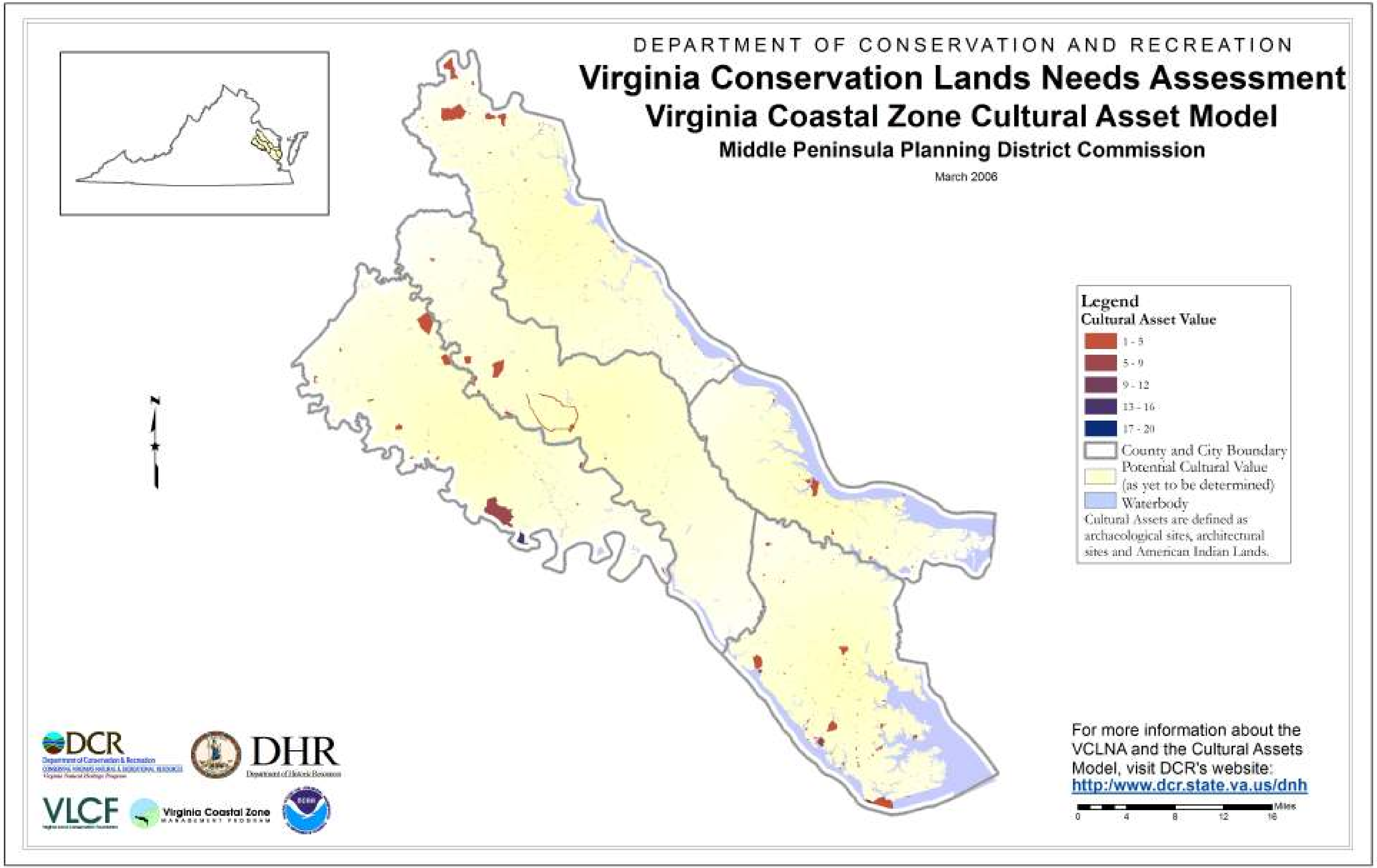


Figure 20. PDC 18 Middle Peninsula PDC Cultural Asset Model.

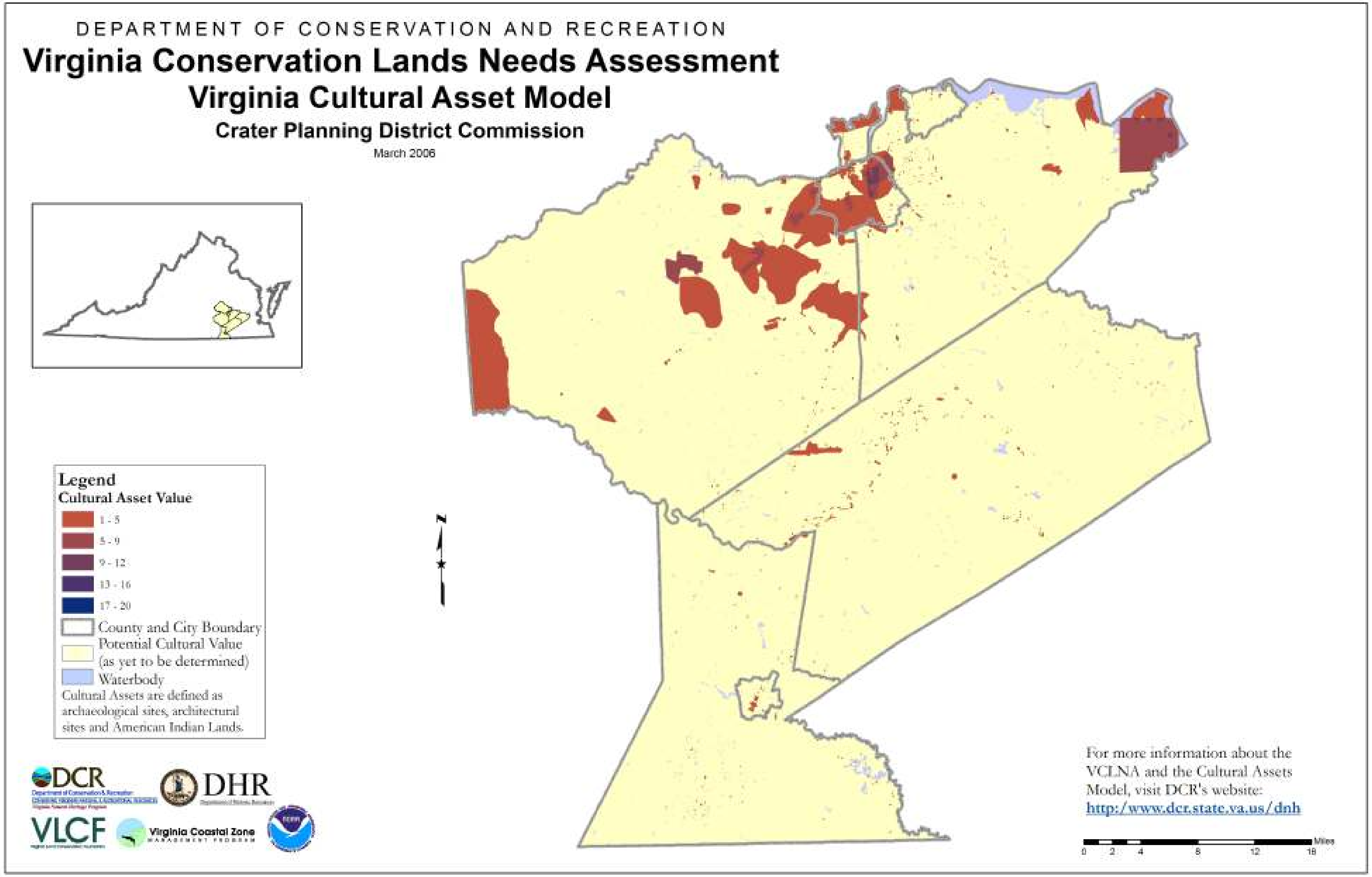


Figure 21. PDC 19 Crater PDC Cultural Asset Model.

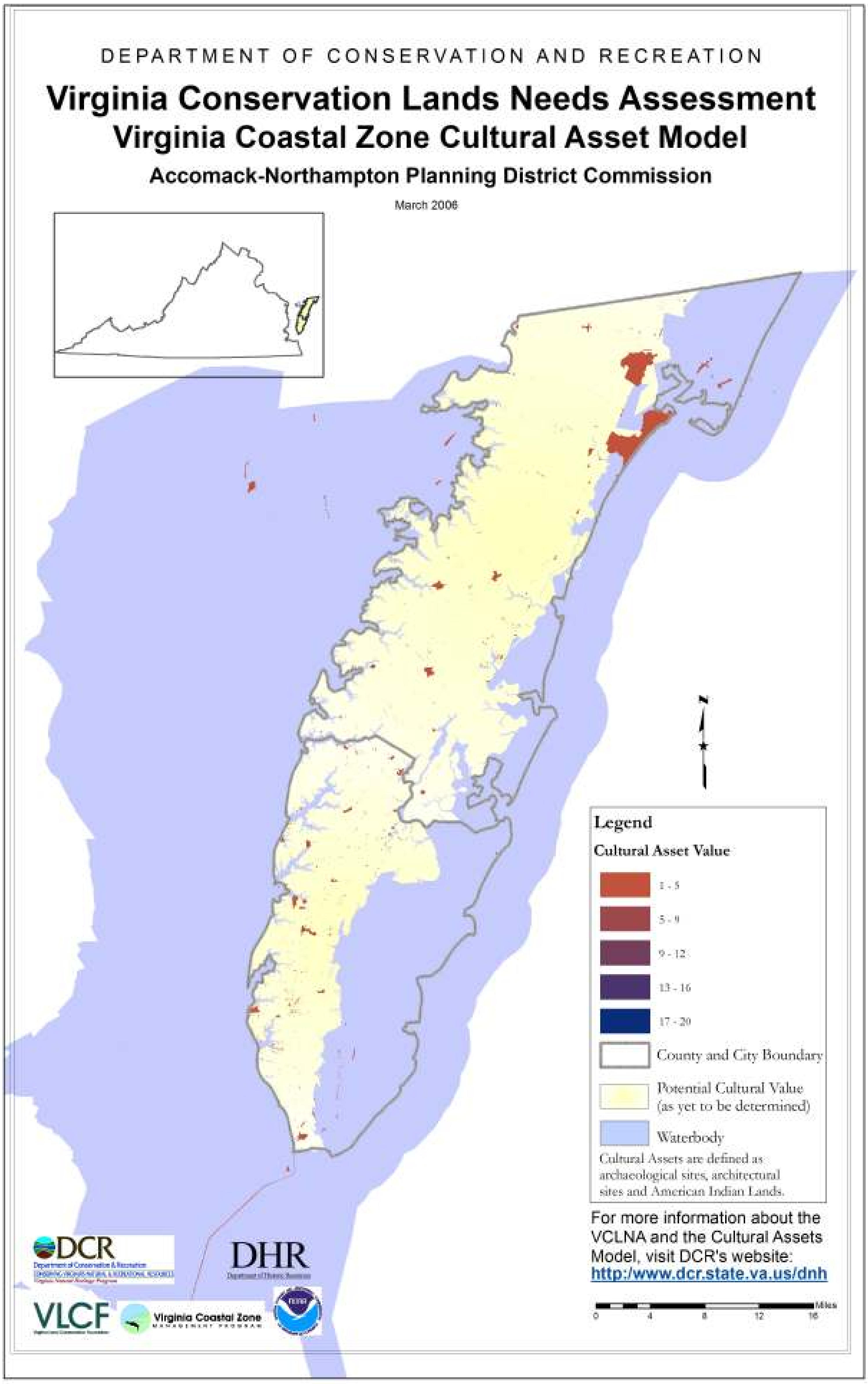


Figure 22. PDC 22 Accomack-Northampton PDC Cultural Asset Model.

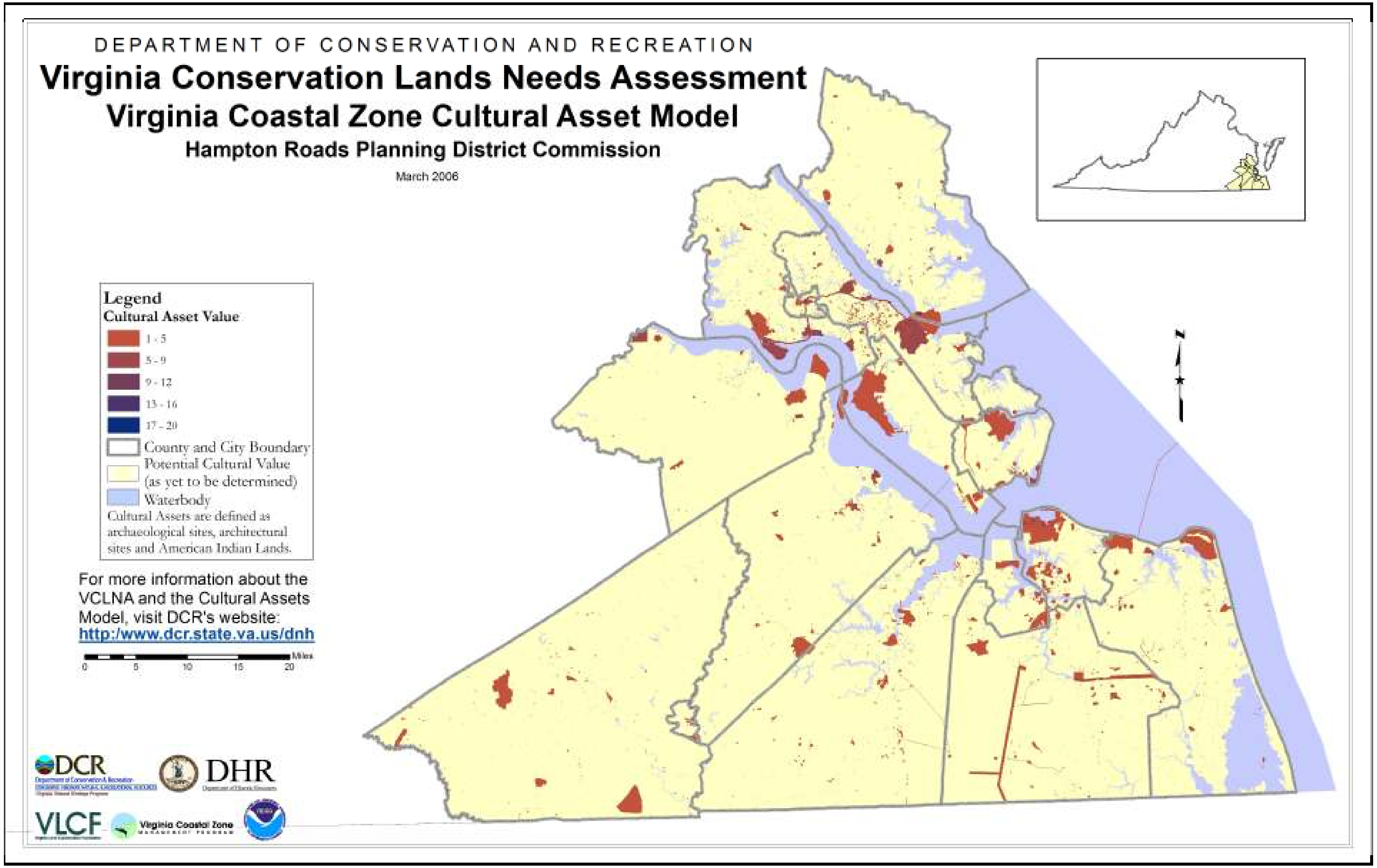


Figure 23. PDC 23 Hampton Roads PDC Cultural Asset Model.

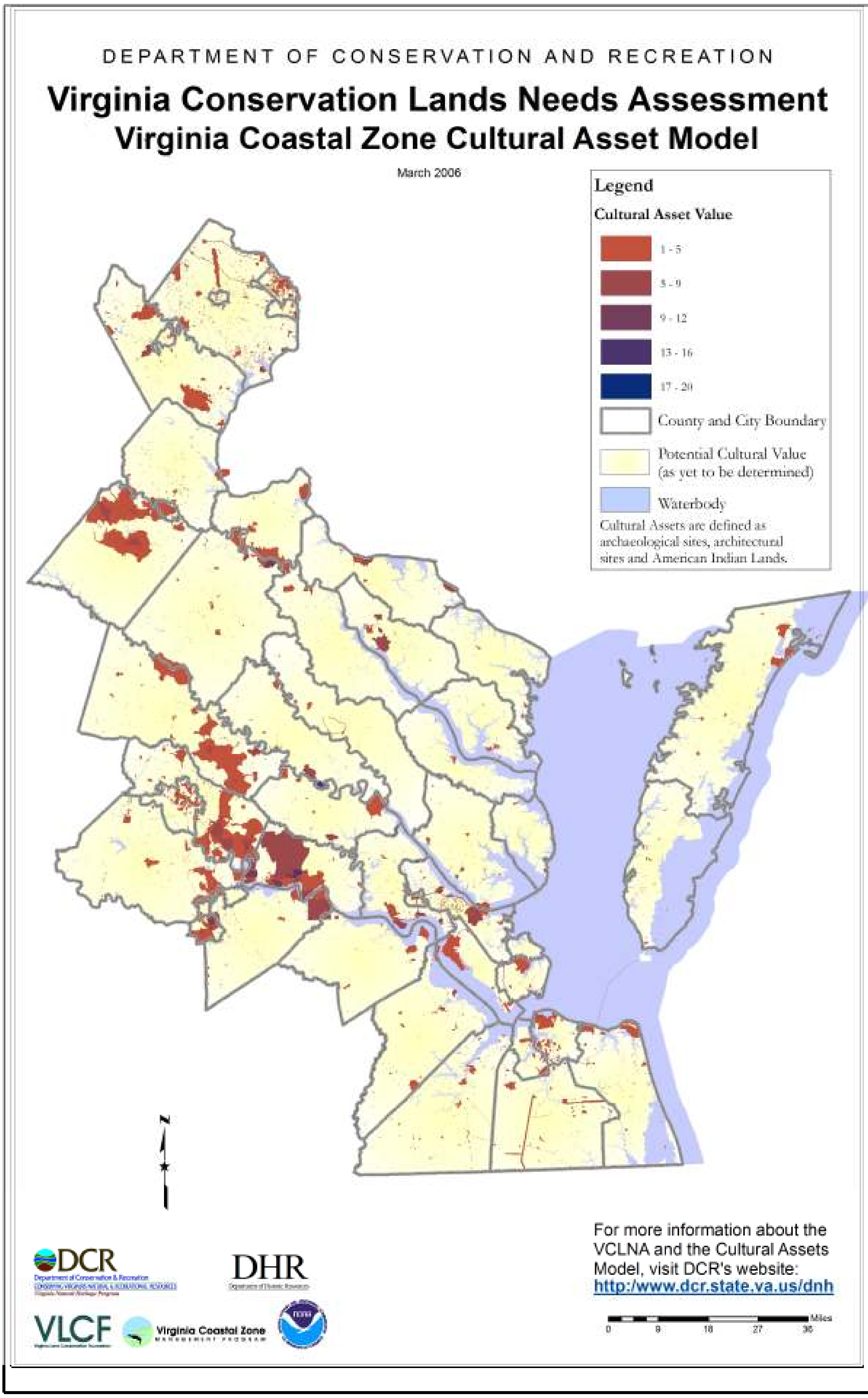


Figure 24. Coastal Zone Cultural Asset Model

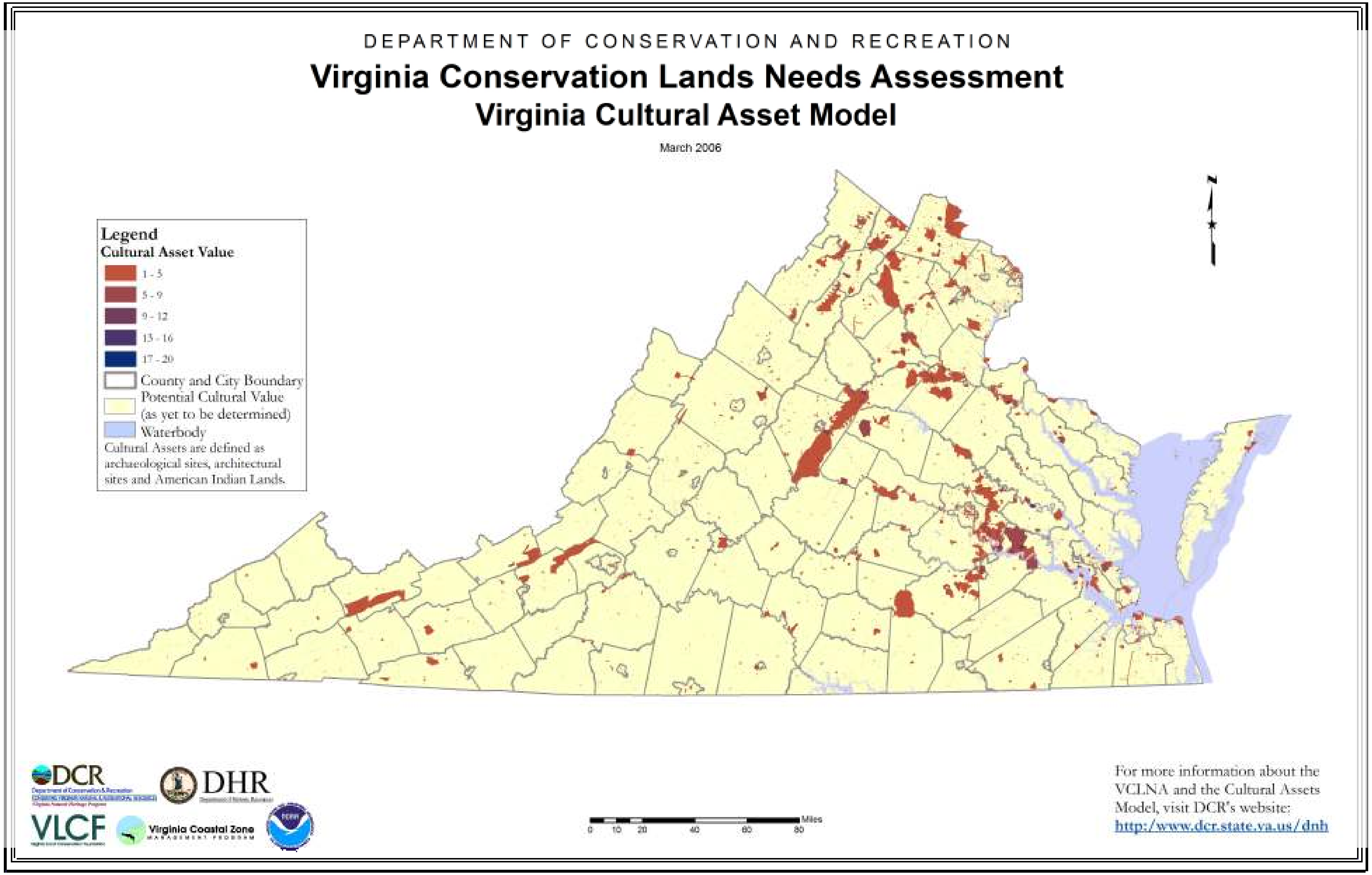
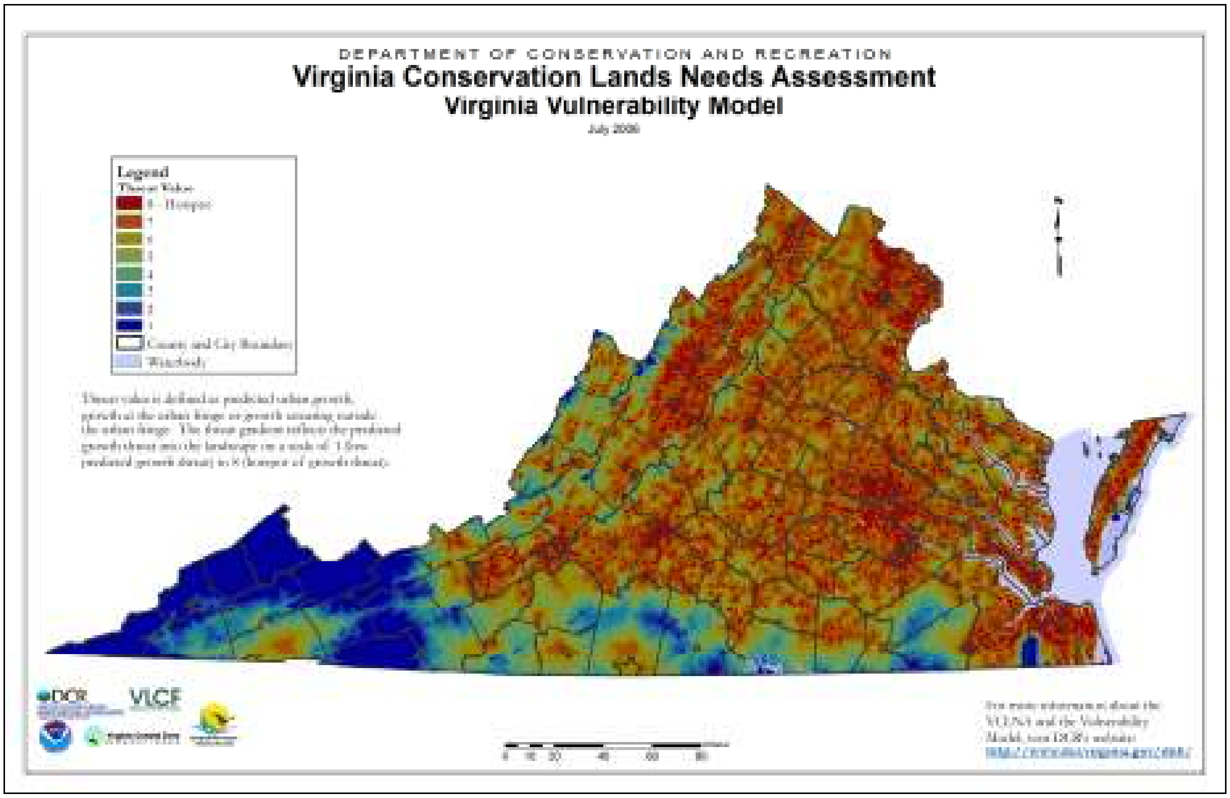


Figure 25. Statewide Cultural Asset Model

Virginia Conservation Lands Needs Assessment
Virginia Vulnerability Model



Virginia Department of Conservation and Recreation Division of Natural Heritage
Virginia DEQ Coastal Zone Management Program

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INTRODUCTION

In 2000, the Virginia population was 7,078,515 and by 2025, it is projected to be the 12th most populous state with 8.5 million people *(STATE POPULATION RANKINGS SUMMARY.* This increase in population is obviously correlated with an increased in housing units and land consumption rates. From 1990 to 2000, Virginia has experienced a 45% increase in imperviousness *(Chesapeake Bay from Space Program)*

In order to assess how growth is occurring across the state, a landscape scale analysis must be done. The Virginia Vulnerability Model was developed in an effort to map predicted growth in Virginia. The growth prediction may be used as an indication of potential land use change from the current use to an urban, suburban or rural use.

In an effort to map the predicted growth in Virginia, four models were developed:

- Virginia Urban Vulnerability Model which shows predicted urban growth
- Virginia Urban Fringe Vulnerability Model which shows the predicted urban fringe, or metropolitan fringe growth.
- Virginia Vulnerability beyond the Urban Fringe Model which show the predicted growth beyond the urban fringe (ex-urban growth).
- Virginia Vulnerability Model which shows a composite of all the vulnerability models integrated into one model representing growth pressures across the urban, suburban and rural landscape.

(E. H. Wilson et al. 2003, R. E. Heimlich and W. D. Anderson, 2001)

The Vulnerability models represent predicted urban growth into the landscape and it is incumbent on the end user to assess what growth represents in terms of sprawl (E. H. Wilson et al. 2003). Urban growth that continues in an unplanned fashion, particularly into previously undeveloped areas, typically has a negative effect on the environment, ecologically, economically and socially (E. H. Wilson et al. 2003, R. E. Heimlich and W. D. Anderson, 2001). As growth and subsequent development continues across the state, remaining resources are being damaged and irretrievably lost.

The development of a GIS vulnerability model puts growth into context in relation to the state; it provides a large scale picture of growth patterns across jurisdictional boundaries. Traditionally state and local government has been reactive to population growth, and while some efforts are being made to control growth, often “strategically directing development to the most favorable areas well in advance of urban pressures” does not happen (R. E. Heimlich and W. D. Anderson, 2001).

The models, detailed above, represent different growth effects. The only model showing all predicted growth effects is the Virginia Vulnerability Model. The Urban Vulnerability Model shows the predicted urban growth into the landscape, it does not include the suburban or rural growth pressures. The Urban Fringe Vulnerability Model shows the predicted urban fringe, also typically called suburban, growth into the landscape, it does not include urban or rural growth pressures. The Beyond the Urban Fringe Vulnerability Model shows predicted growth outside of the urban fringe, or rural growth pressures, it does not include urban or suburban growth pressures.

Application of the Vulnerability Model

Some general categories of uses to which the vulnerability model can be applied include:

- Targeting – to identify targets for protection activities
- Prioritizing – to provide primary or additional justification for key conservation land purchases and other protection activities.
- Local planning – guidance for comprehensive planning and local ordinance and zoning development.
- Assessment – to review the state of the land and assess growth in context of the landscape
- Land Management – to guide property owners and public and private land managers in making land management decisions that enhance ecological, social and economic services
- Public Education – to inform the citizenry about the development and growth of their community, helping them stay informed about the state of growth of their area.

The Vulnerability Model serves as a base model, upon which local datasets can be added, such as zoning information, comprehensive plans, parcel data, septic suitability information and any other datasets which may help drive local decision making processes. The constraints of a statewide model include the incorporation of existing, statewide GIS datasets. Incorporation of datasets such as individual locality septic sewer information may not be available statewide and are not included in the model since the effect would skew overall model results. Individuals should use the Vulnerability Models and incorporate any additional datasets as needed to make informed decisions. It is at this local level the end user may be able to draw his / her own conclusions on growth, sprawl and the impending consequences.

METHODOLOGY

Data methods were based on the Chesapeake Bay Program's Vulnerability Model. The methodology has been modified in some places and changed in others to reflect Virginia specific needs. Please refer to the Chesapeake Bay Program's Resource Lands Assessment (RLA) for a review of the CPB RLA Vulnerability Model methodology (http://www.chesapeakebay.net/rla.htm).

Livable area road density

Livable area road density was calculated at the block group level to derive a per pixel housing value.

A focal sum was run in GRID to generate a road density grid using TIGER road data and a 1 kilometer window. RESAC (Goetz 2004, UMD-RESAC 2000) data derived from the VANLA analysis (see the VANLA methodology discussion on Base Data) was classed with livable and non-livable areas, with non-livable areas set as open water, emergent wetlands, transportation and extractive. The National Elevation Dataset (NED) was used to derive a slope grid. The slope grid was classified as non-livable where slope was greater than 20%.

A final grid was generated to show livable area road density (called ex_lands).

Housing Allocation

A housing allocation procedure was run to estimate the total number of single family housing units per pixel. The livable area road density grid was summarized by unique block group for the 1990 and 2000 census block groups.

The relative percentage of block group road density per pixel was calculated and then single family detached housing units per pixel grid was calculated (grid representing proportional # of housing units per pixel).

Lot Size Estimation

A regression model was developed to predict average lot size from road density values in order to determine land consumption rates.

A 1 square mile grid was generated and called REGNET (for regression fishnet). The REGNET grid was determined to be the effective planning unit. Virginia localities representing urban, suburban and rural areas were contacted for GIS parcel and zoning data (Table 1, Table 2). Parcels not zoned residential as determined by the Municode or Zoning Ordinance were deleted. Parcels that were zoned residential were attributed with a GIS_Acreage field (double type). The acreage calculated, the layer reprojected to Lambert NAD 83, converted to centroid, and then merged into one feature class. In ArcMap, a spatial join was run on the REGNET grid and the parcel centroids. The unique ID of the centroid was set to REGNET_ID.

To calculate road density values, 0 values in the ex_lands2 grid were set to NO DATA for averaging purposes and called exld_null.

Zonal Statistics were used to summarize exld_null in ArcMap (this is the average road density per unique REGNET grid cell). The MEAN road density value was calculated into the RDD_exnull attribute of REGNET feature class. Selected from the REGNET layer where rdd_exldnull > 0 and export as REGNET2. To remove any fragment areas, REGNET2 cells that were completely within the Virginia state boundary were selected and exported to another feature class called REGENT3. Queries were run in Access to calculate the average GIS acreage for each unique REGNET_ID.

Statistical Analyses

Statistical analyses were performed in SAS System 9.1. The full dataset included a total of 35 cities and counties from whom parcel information was obtained (see Table 1). Data for GIS Acreage less than 10 acres was subset for the regression analysis. The acreage was subset at 10 acres to establish a group of data with which to test full and submodels. Acreage above 10 acres was highly variable in the datasets indicating a potential lack of relationship between road density and parcel size.

Univariate statistics were run in SAS System 9.x to test for data normality. Tests on the full dataset indicated non-normal data. The GIS Acreage was transformed with a natural log transformation. Univariate statistics and residual plots indicated data were normal.

Regression analyses (PROC REG) were run in SAS to derive regression equation:

$$\textbf{average lot size} = \mathbf{0.9582e^{-0.0000025645(RDD\_exnull)}}$$

r-sq = .55

p < .0001

This regression is applicable for lot sizes up to mean 10 acres as the regression data went up to 10 acre lot sizes total.

This equation provides a way to calculate a land consumption rate that will be used in the next step.

Growth Hot Spots

This process identified areas considered to be hot spots for population growth. Attributes were added to REGNET3 (double) for the sum of the single family detached housing units per pixel grid derived from the housing allocation procedure for 1990 block group (SHU_90) and 2000 block group (SHU_00); the change in housing units was then calculated into SHU90_00 (shu_00 – shu_90); a field was added called MeanLotSize (double type) and the average lot size was calculated into the field using the regression formula:

MeanLotSize = 0.9582 * exp [-0.0000025645*(RDD_exnull)]

r-square = 0.5557

p-value < .0001

The change in land consumption could then be calculated into CNVRT90_00:

CNVRT90_00 = shu90_00 * MeanLotSize

In ArcMap, Spatial Analyst was used to calculate the change in impervious surfaces from 1990 to 2000 using RESAC impervious surface data (diffimp00_90 = [vaimp00_lam83 – vaimp90_lam83]) (Goetz 2004, UMD-RESAC).

A 3x3 filter was run on the difference in impervious surface grids to smooth the data. A 9 x 9 filtered grid filter misrepresented impervious surface change.

The change in impervious surface data from 1990 to 2000 was summarized by REGNET_ID and the mean was calculated into imp90_00_2 attribute in REGNET.

Impervious Hot Spots

This process identified areas considered to represent significant impervious growth.

The summarized mean of the change in imperviousness (imp90_00_2) was normalized with a log transformation and calculated into a field called LNIMP90_00_2 (double). SAS PROC MEANS was run on LNIMP90_00_2 where values > 0 (alpha = .10, Standard Error = 1.64) (because this is an upper one tail test, so p value = .05) to determine the Upper Confidence Limit to select out impervious hotspots. Upper CL = 3.335. REGNET cells that had a LNimp90_00_2 value greater than or equal to 3.335 were exported out as impervious hot spots (called hspotsimp).

Residential Land Conversion Hot Spots

This process identified areas considered to represent significant changes in residential land conversion / land consumption.

The Rural-Urban Commuting Area Codes (RUCA) allow for the identification and incorporation of urban, suburban and rural effects. Data was downloaded from http://www.ers.usda.gov/briefing/rural/data/ruca/rucc.htm. The RUCA codes were joined to U.S. Census Tracts, and the tracts were reclassified using the Chesapeake Bay Program's RLA as:

Grow Zone	Reclassified category	Original RUCA
"1"	Urban Core Zone =	Metropolitan-area cores (1.0, 1.1)
"2"	Urban Commuting Zone =	Metropolitan-area high commuting (2.x), Metropolitan-area low commuting (3.x), and all secondary flows to Urban Areas (ranging from 5 – 50%).
"3" or "4"	Rural Zone =	All other areas (encompassing Large town, Small town, and Rural areas lacking secondary flow to Urban Areas).

All RUCA polygons where the grow zone = 1 and acreage > 50 were selected. A Select by Location was used to select the REGNET polygons that had their center in the selected RUCA polygons. The data was exported to a new feature class called Urban_Core.

All RUCA polygons where the grow zone = 2 and acreage > 50 were selected. A Select by Location was used to select the REGNET polygons that had their center in the selected RUCA polygons. The data was exported to a new feature class called Urban_Commute.

All RUCA polygons where the grow zone = 3 and acreage > 50 were selected. A Select by Location was used to select the REGNET polygons that had their center in the selected RUCA polygons. The data was exported to a new feature class called Rural.

The change in land conversion was normalized with a long transformation. Statistical analyses were then run in SAS to calculate the upper confidence limit. The upper confidence limit was the statistically defined value to be used to identify hot spots. Statistics were run on the urban core, urban commute and rural feature classes to find the significant value from each dataset. This value was then used to select out urban core hotspots, urban commute hotspots and rural hotspots.

Hotspots

Impervious surface hotspots and urban hotspots were merged (with a union) to create new feature class called hotspots_1. Impervious surface hotspots and urban commute hotspots were merged to create a new feature class called hspots_2. Impervious surface hotspots and rural hotspots were merged to create a new feature class called hotspots_3. Each feature class was then converted to a 30 meter grid with the Spatial Analyst extension in ArcGIS.

Threat Grids

Travel Time

This process was used to create a travel time grid to incorporate the influence of distance to hot spots on surrounding areas.

Tiger Roads data was downloaded and attributed with a roads time attribute. Travel time was calculated from CFCC codes and RLA methodology:

CFCC	Description	MPH	TTIME (minutes per meter * 100K)
A1	Primary highway with limited access (e.g., Interstates)	65	57
A2	Primary road without limited access (mainly US Highways)	55	68
A3	Secondary and connecting roads (e.g., State and County highways)	40	93
A4	Local, neighborhood, and rural roads	30	124
A6	Road with special characteristics (ramps, traffic circles, etc.)	15	249
Other	A5x's and A7x's (off-road trails, driveways, alleys, etc.)	5	746

65 * 1.60934 = 104.6 kph * 1000/60 = 1743 meters per minute, 1/1743 = 0.000574 minutes per meter

The Tiger roads were converted to a 30 meter grid with Spatial Analyst in ArcGIS. NoData values were set with a TTIME of 746 (consider off road travel per RLA):

Individual threat grids were calculated in ArcGRID for the urban growth, suburban growth and rural growth threats.

Threat

The threat_1 (urban growth threat), threat_2 (urban fringe growth) and urban_3 (outside the urban fringe growth) were displayed using manual breaks in ArcMap, with a higher threat value indicates a great threat:

THREAT	GRID VALUE	TRAVEL TIME (minutes)
5	0	0
4	0.001 - 1,500,000	0 to 15
3	1,500,000.001 - 3,000,000	15 to 30
2	3,000,000.001 - 6,000,000	30 to 60
1	6,000,000.001 - 12,000,000	60 to 120

Each grid threat grid was multiplied by .33 to get a proportional value of threat / travel time in order to generate a summed threat grid of all three layers. The three layers were then added together in ArcGRID to generate an integrated, statewide growth prediction grid, called threat_sum.

The threat_sum grid (compiled threat model showing predicted growth in the urban, urban fringe and outside the urban fringe areas) was displayed with 8 manual breaks in ArcMap (higher threat value indicates a greater growth threat):

THREAT	GRID VALUE	TRAVEL TIME (approx minutes)
8	0	0
7	0.001 - 495,000	0 to 5
6	495,000.001 - 990,000	5 to 10
5	990,000.001 - 1,485,000	10 to 15
4	1,485,000.001 - 1,980,000	15 to 20
3	1,980,000.001 - 2,475,000	20 to 25
2	2,475,000.001 - 2,970,000	25 to 30
1	2,970,000.001 - 3,420,000	30 to 35

The gradient is spread at smaller increments on the threat_sum grid because it proportionally reduced the original number to add into the final grid. The gradient division was calculated as 1500000 * .33 = 495000. This more accurately represents hotspots that may have been in one layer and not in another, therefore getting a sum value greater than zero.

Topology

A topology feature class was created for UrbanGrowthThreat, UrbanFringeGrowthThreat, GrowthOutsidetheUrbanFringeThreat and VulnerabilityModel_AllThreat feature classes for the following rules:

i. Must Not Overlap
ii. Must Not Have Gaps

Each feature class has been topologically validated and cleaned.

Model Validation

The original version of the Vulnerability Model was sent to:

- Crater PDC
- Hampton Roads PDC
- Goochland County
- Middle Peninsula PDC

- Northern Neck PDC
- Thomas Jefferson PDC

Comments indicated the model was representing too much land as being hotspots or heavily weighted to indicate potential growth.

The model was re-run with statistical analyses to pick out values representing statistically significant hotspot values. Four models were developed instead of one overall vulnerability model to account for urban, suburban and rural growth pressures as individual issues, instead of compiling into one overall model. The data was becoming lost in over-generalization of values in order to develop a single model.

The final model was passed through an internal review at the Division of Natural Heritage.

The VCLNA website will be equipped to receive comments regarding the Vulnerability model results. These comments will be reviewed and assessed in relation to the model; this will enable a continuing evaluation of the model. The Vulnerability Models represent prediction models, ground truthing hotspots at this point in time may not prove ineffective as the model projects out ten + years in time.

RESULTS

Maps were produced for the entire Coastal Zone and the Planning District Commissions and included as part of the final report. The report is available online and on CD by request and includes:

- Maps showing:
    - Virginia Urban Vulnerability Model
    - Virginia Urban Fringe Vulnerability Model
    - Virginia Vulnerability outside the Urban Fringe Model
    - Virginia Vulnerability Model which shows a composite of all the vulnerability models integrated into one model representing growth pressures across the urban, suburban and rural landscape.
- A report detailing the methodology
- Metadata
- Layer files
- Four (4) GRID coverages representing the above detailed models.
- Four (4) shapefiles representing the above detailed models.
- An ArcGIS geodatabase with threat feature classes.

DISCUSSION

The Vulnerability model may serve as a guide to state and local government, consultants, and developers as to the location of growth patterns, particularly in relation to the current environment. The model can be used alone or integrated with other datasets, such as the VCLNA Cultural Model or Ecological Model, to identify which cultural resources or ecological cores are most at risk to these growth pressures. The model may also be used to help guide local land use planners in the development of their comprehensive plans in an effort to control growth and subsequent development within their jurisdiction. It is important to look at the landscape as a whole and assess how growth may impact the environment, what remaining farmland or timberland is available or how water quality will be affected, before more development is introduced.

The models serve as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/dnh/vclna.htm.

FUTURE APPLICATIONS

Additional Data Incorporation

Development of a statewide model constrains the model to available statewide datasets. The Vulnerability Model serves as a base growth prediction model developed on a ten year increment of data, projecting out to approximately ten years and more into the future. It is important for the end user to apply specific datasets as needed to make decisions with the model.

It is difficult to model parameters that influence growth and development, such as politics or economic influences, particularly at a statewide scale. Local knowledge should be applied to the model to assess the growth patterns and influences at a local scale.

Additional datasets that can be applied to the model to assess actual growth versus predicted growth may include:

- Soils data in an attempt to model septic sewer capacity as an influence on growth / development
- Economic development data to identify areas promoted for development, such as enterprise zones.
- Comprehensive plans
- Zoning information

Table 2. List of locality parcel data contributors.

LOCALITY
Albemarle
Alexandria
Arlington
Augusta
Botetourt
Campbell
Chesterfield
Covington
Culpeper
Fairfax
Frederick
Gloucester
Goochland
Greene
Hanover
Harrisonburg
Henrico
Henry
James City County
King George
Louisa
Montgomery County
Newport News
Pittsylvania
Pulaski
Richmond City
Roanoke
Rockingham
Shenandoah
Spotsylvania
Stafford
Suffolk
Virginia Beach
Wise
York

Table 3. List of cities and counties used in the final regression model.

REGRESSION DATA
Alexandria
Arlington
Chesterfield
Fairfax
Hanover
Louisa
Pulaski
Richmond City
Virginia Beach

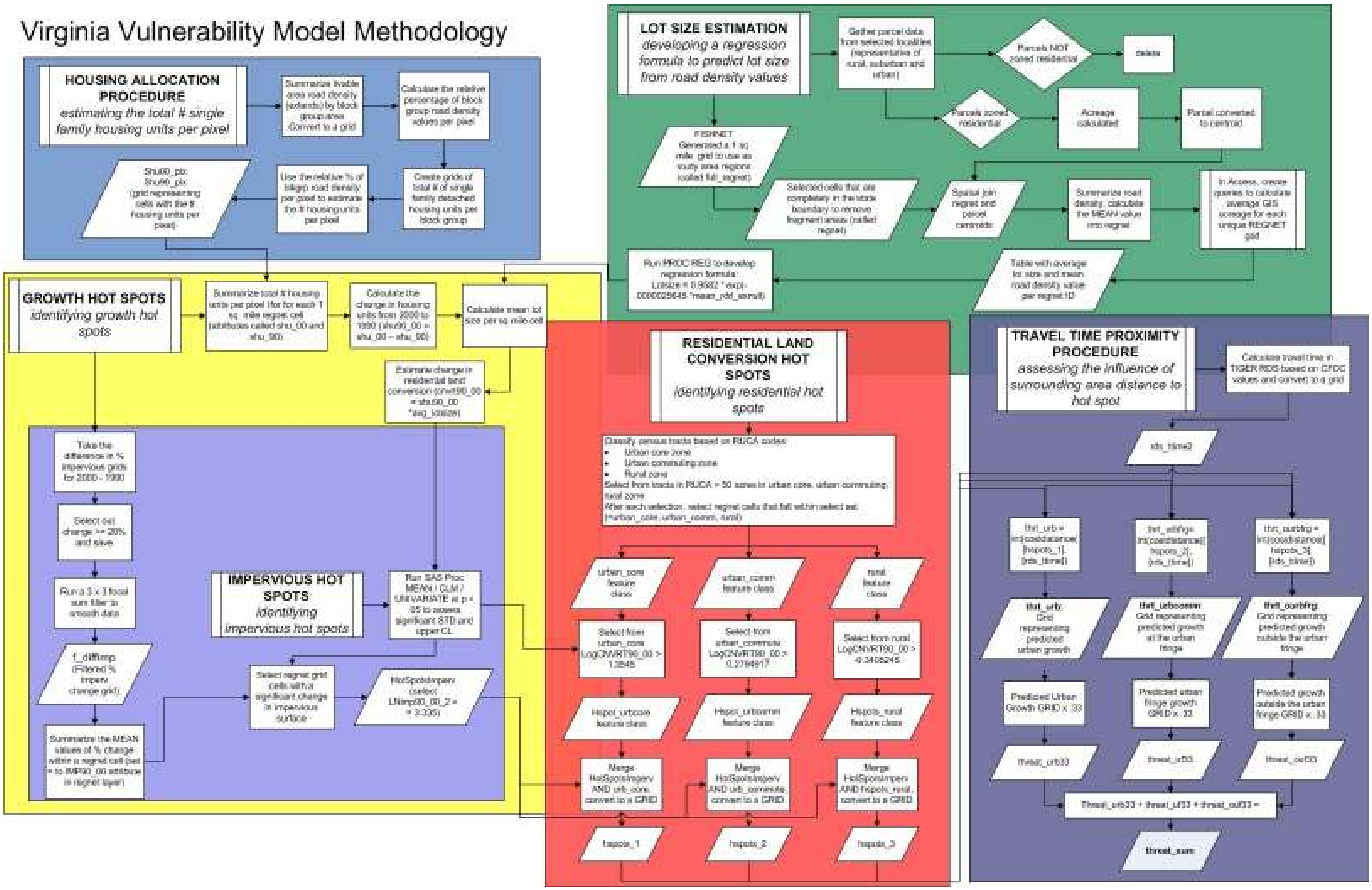

Figure 26. Vulnerability model methodology overview diagram.

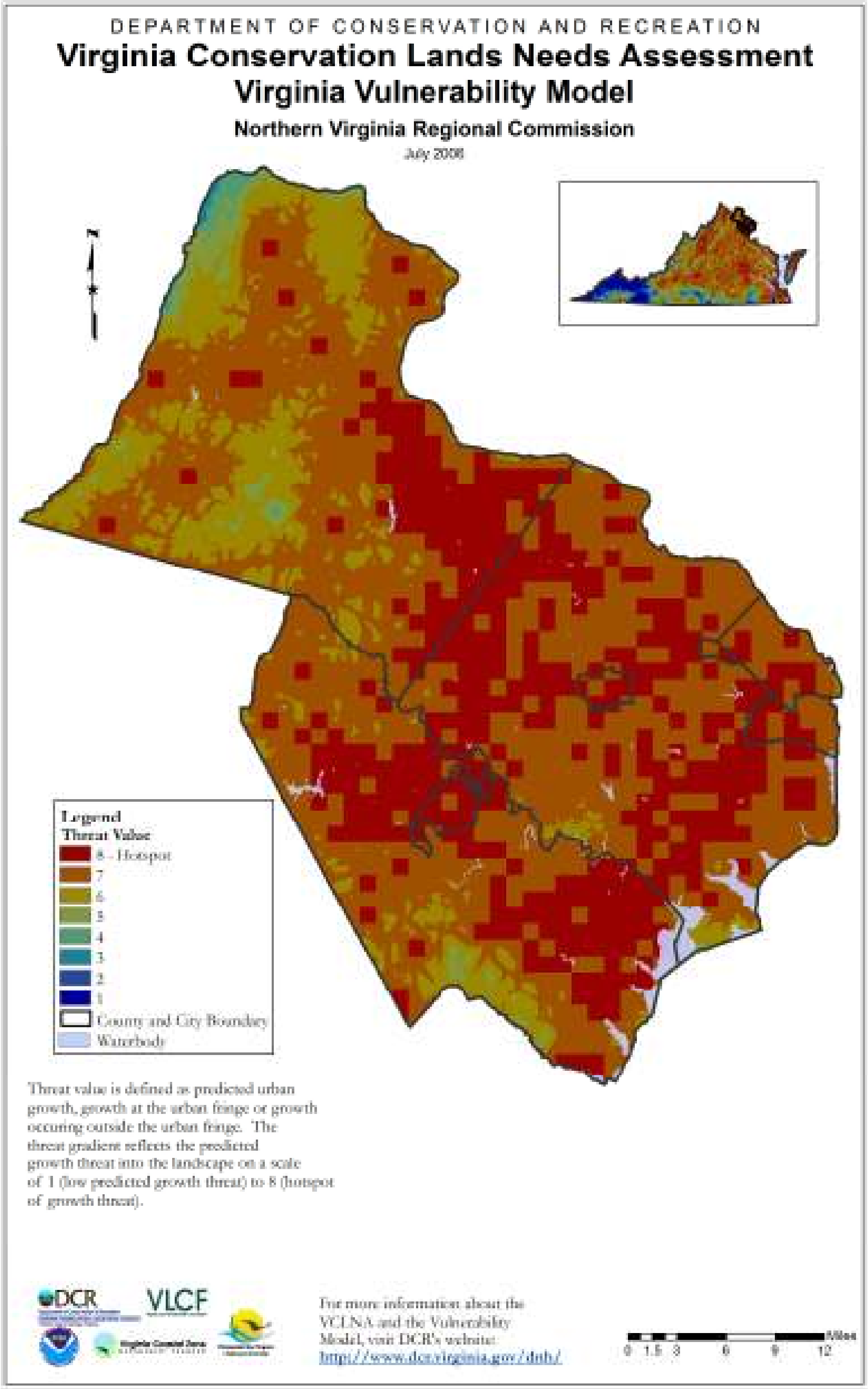

Figure 27. PDC 8 Northern Virginia Regional Commission Vulnerability Model.

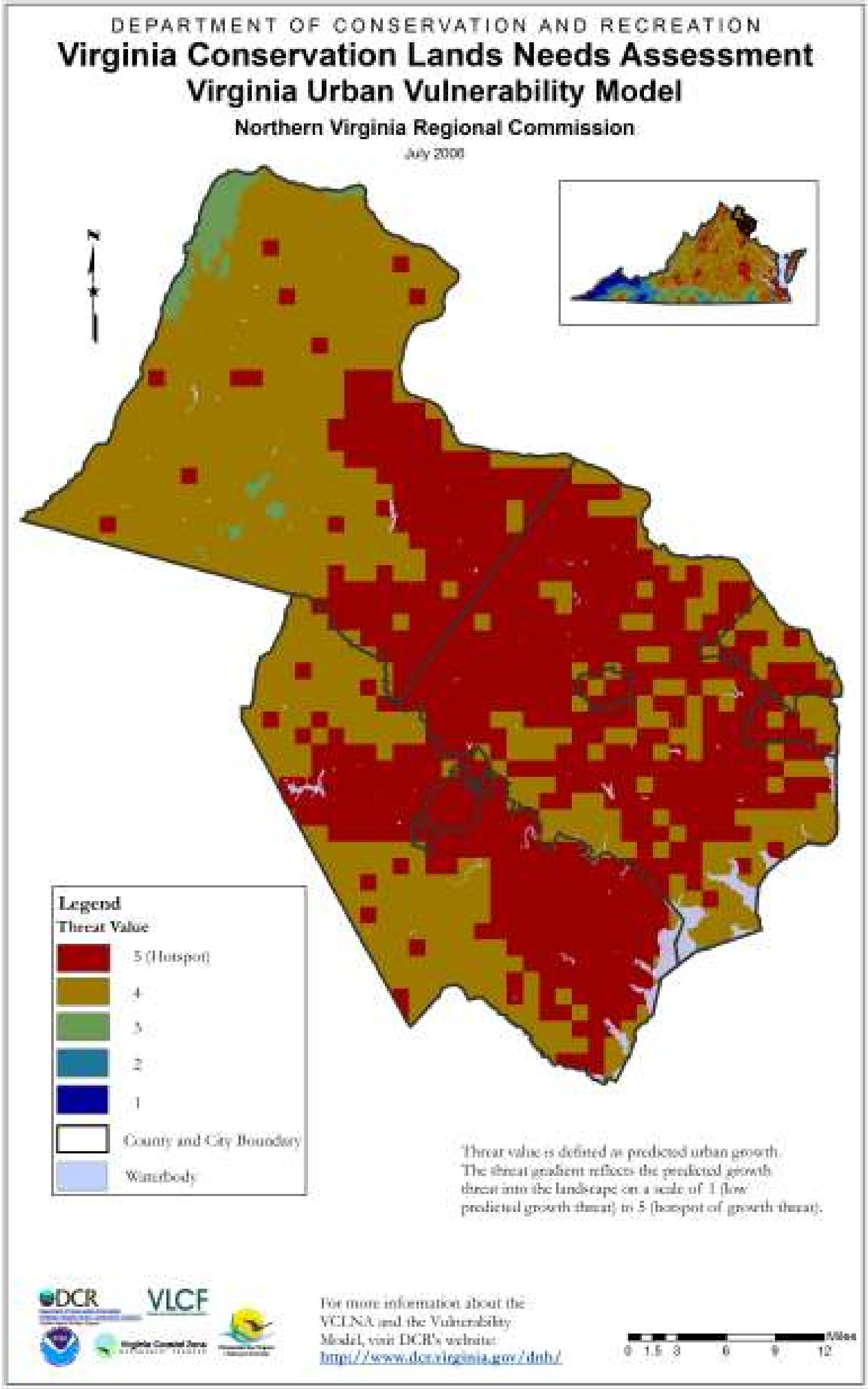

Figure 28. PDC 8 Northern Virginia Regional Commission Urban Vulnerability Model.

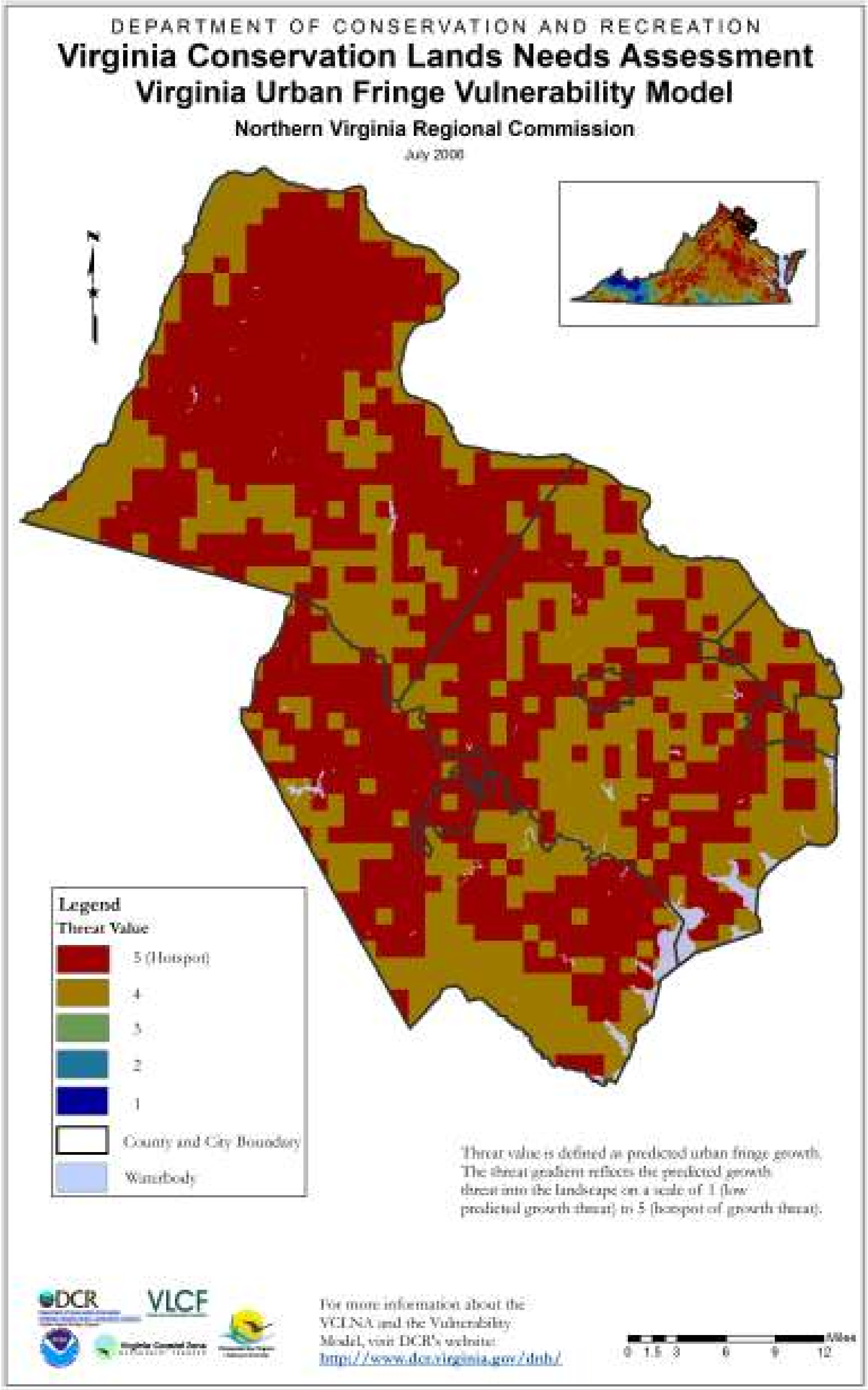

Figure 29. PDC 8 Northern Virginia Regional Commission Urban Fringe Vulnerability Model.

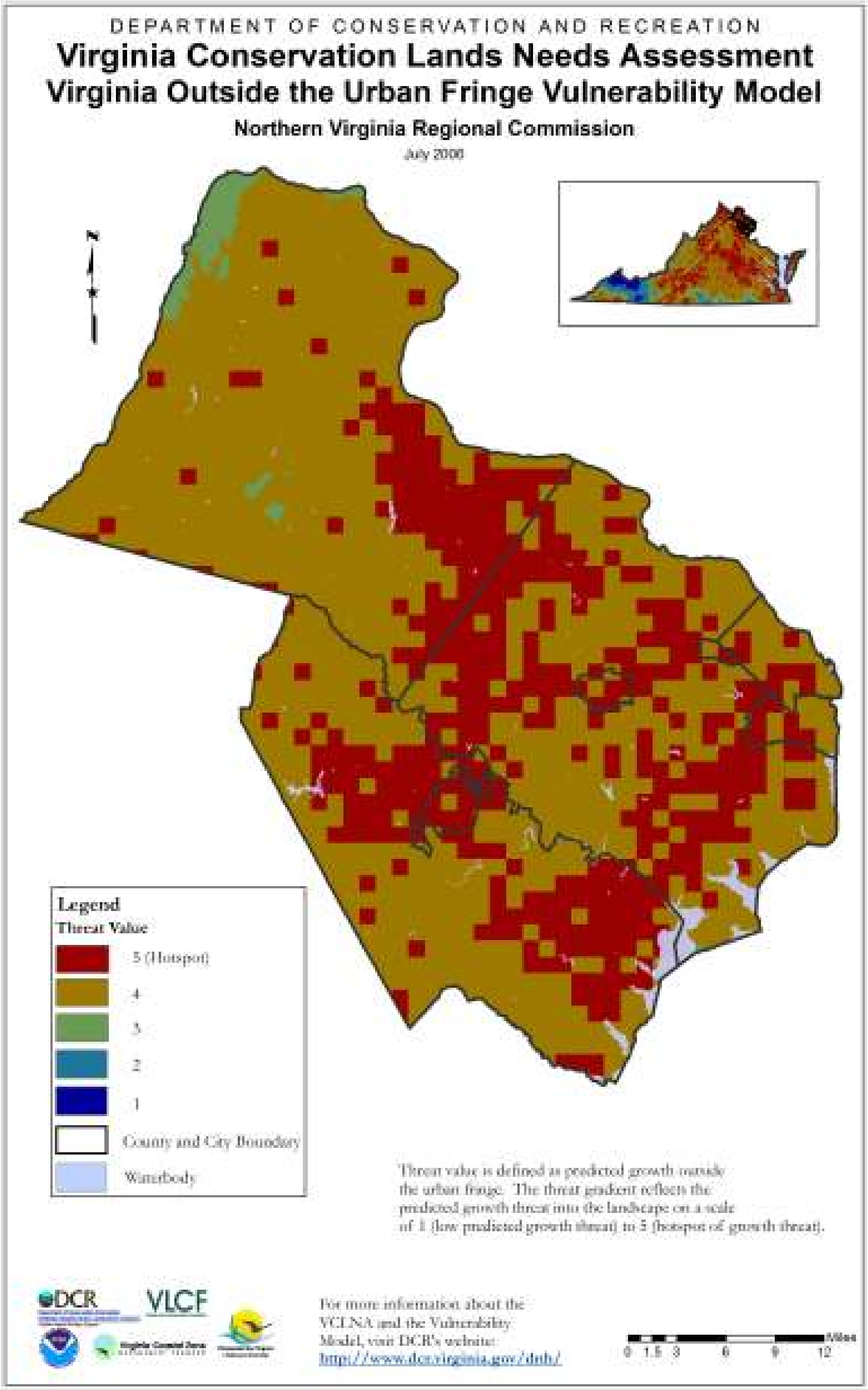

Figure 30. PDC 8 Northern Virginia Regional Commission Outside the Urban Fringe Vulnerability Model.

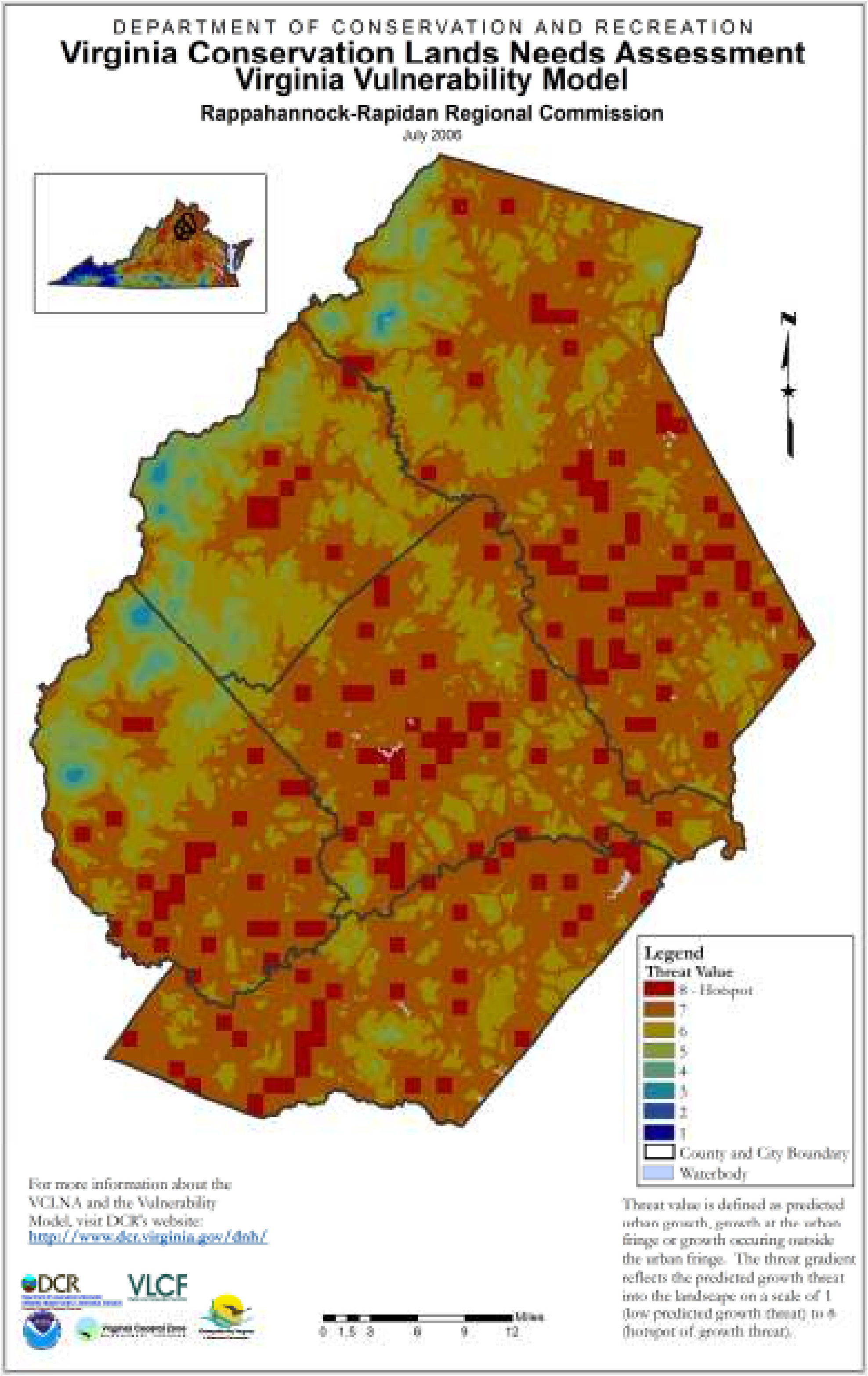

Figure 31. PDC 9 Rappahannock-Rapidan Regional Commission Vulnerability Model.

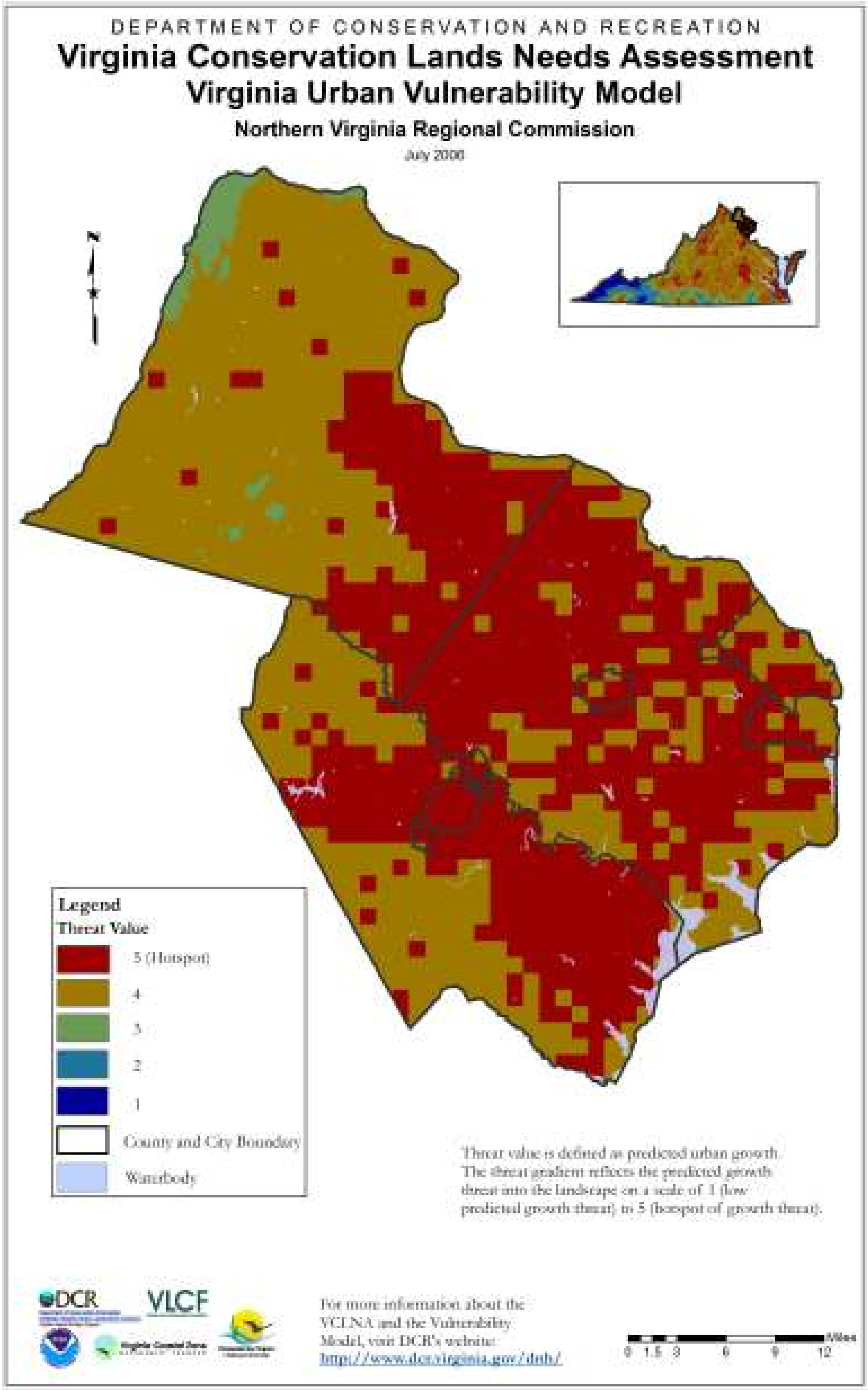

Figure 32. PDC 9 Rappahannock-Rapidan Regional Commission Urban Vulnerability Model.

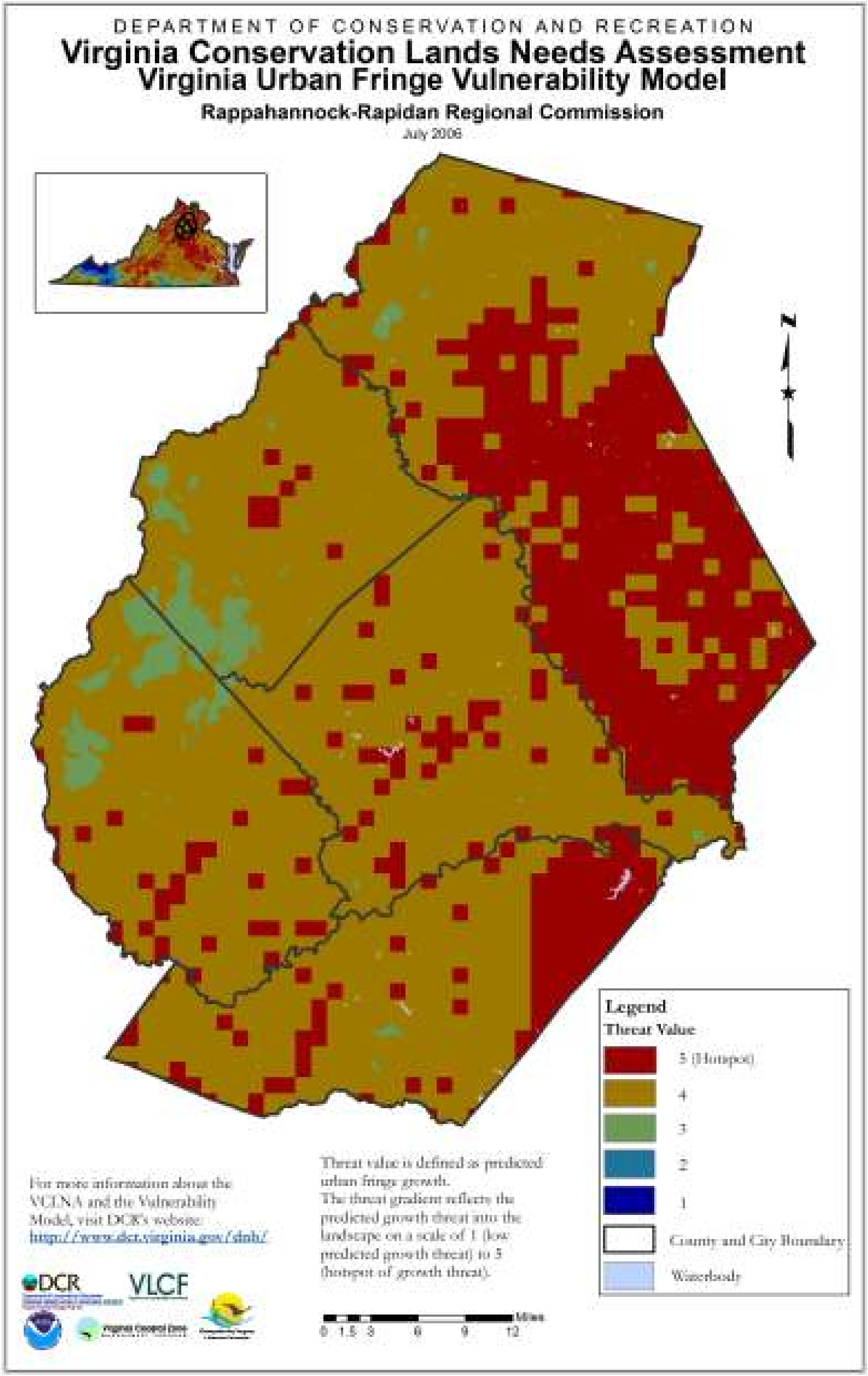

Figure 33. PDC 9 Rappahannock-Rapidan Regional Commission Urban Fringe Vulnerability Model.

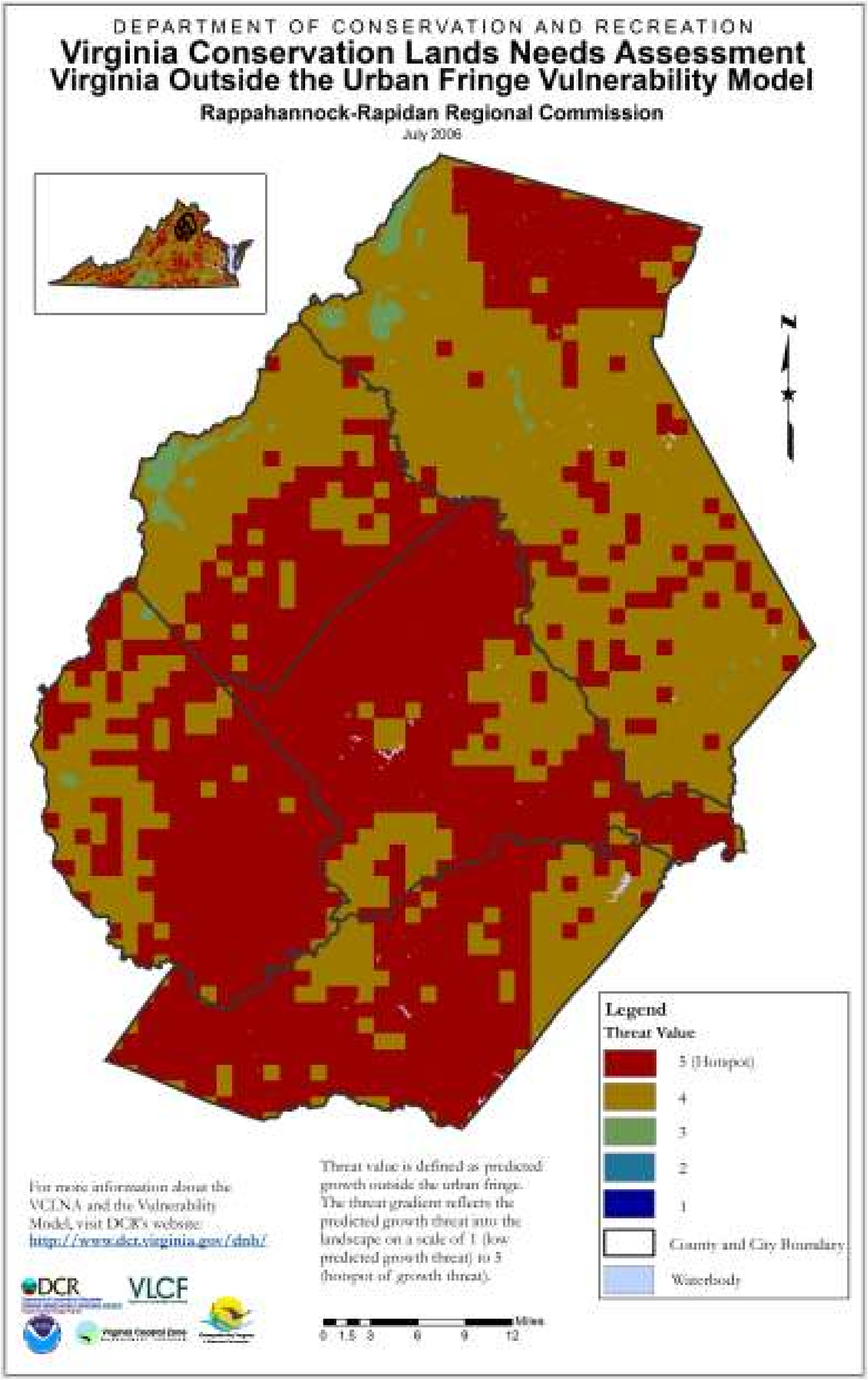

Figure 34. PDC 9 Rappahannock-Rapidan Regional Commission Outside the Urban Fringe Vulnerability Model.

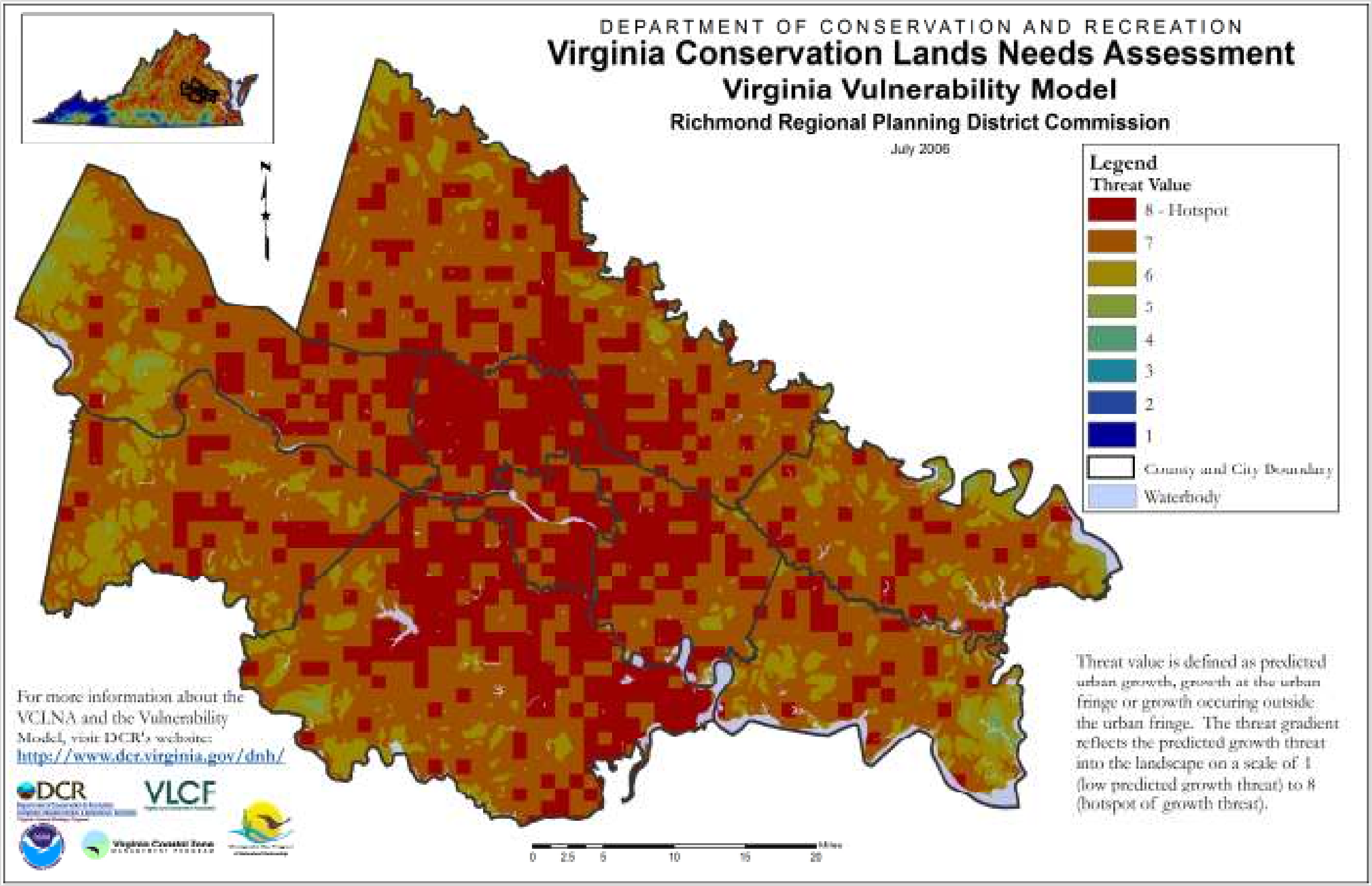

Figure 35. PDC 15 Richmond Regional Vulnerability Model.

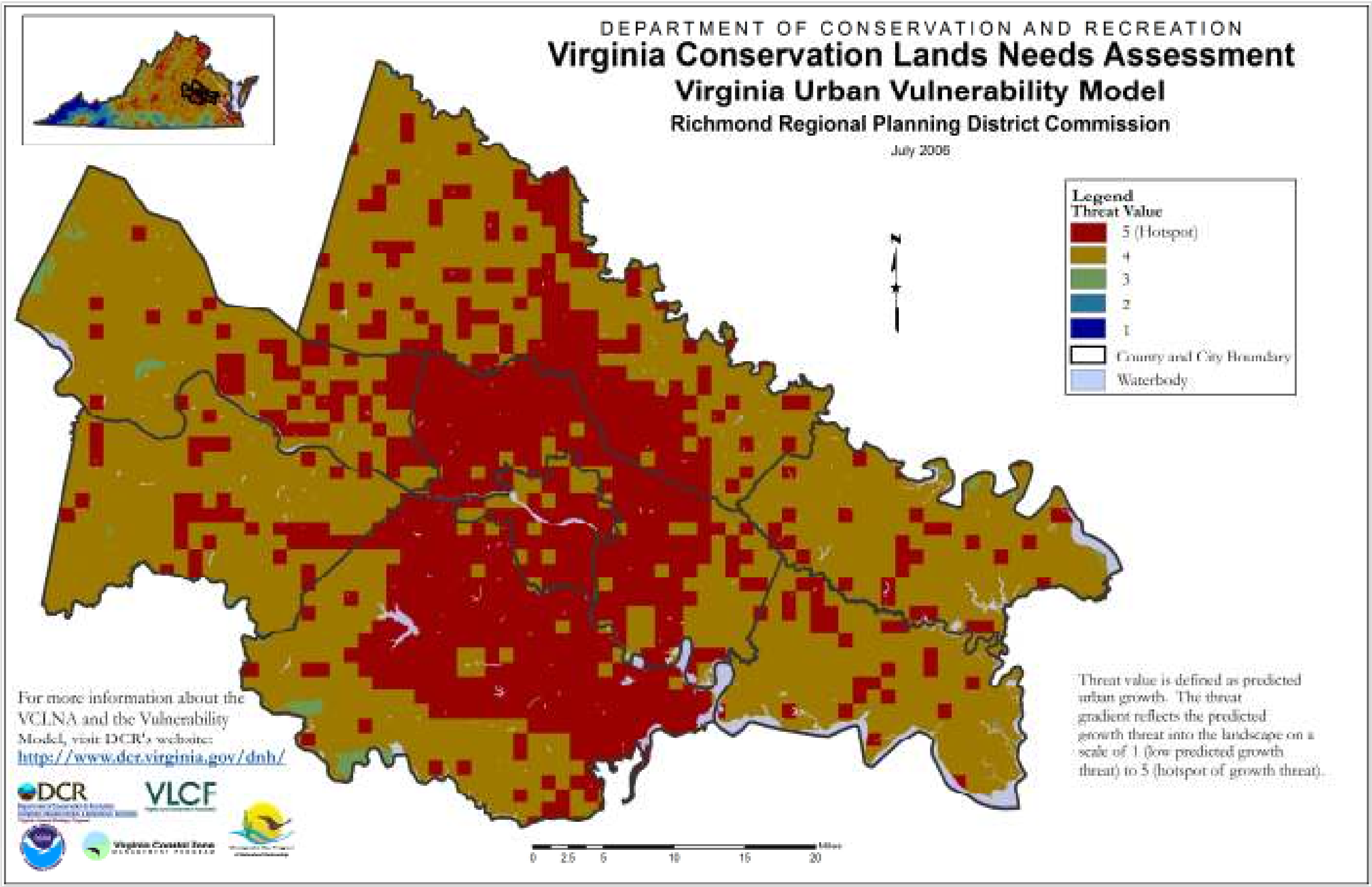

Figure 36. PDC 15 Richmond Regional Urban Vulnerability Model.

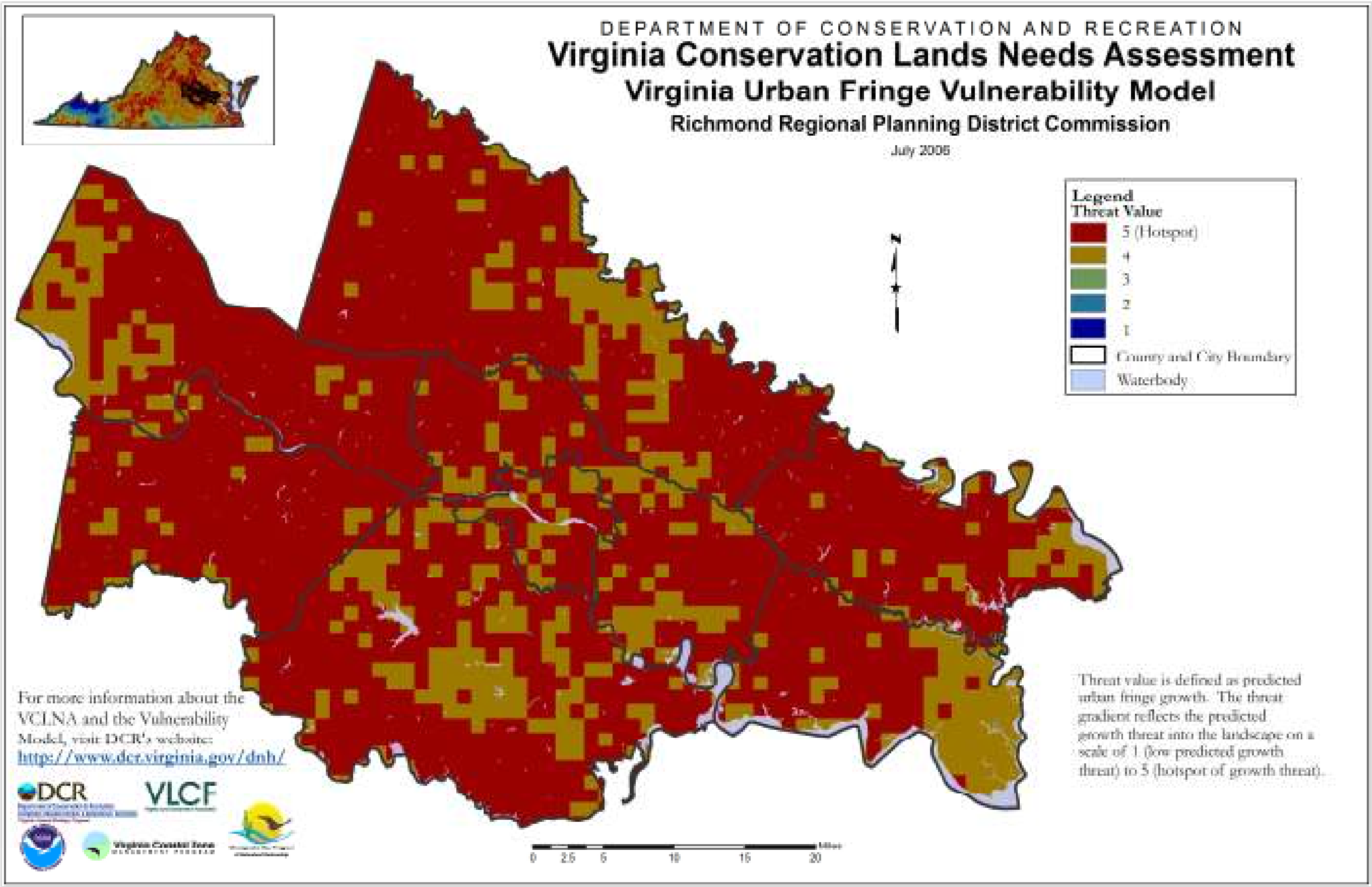

Figure 37. PDC 15 Richmond Regional Urban Fringe Vulnerability Model.

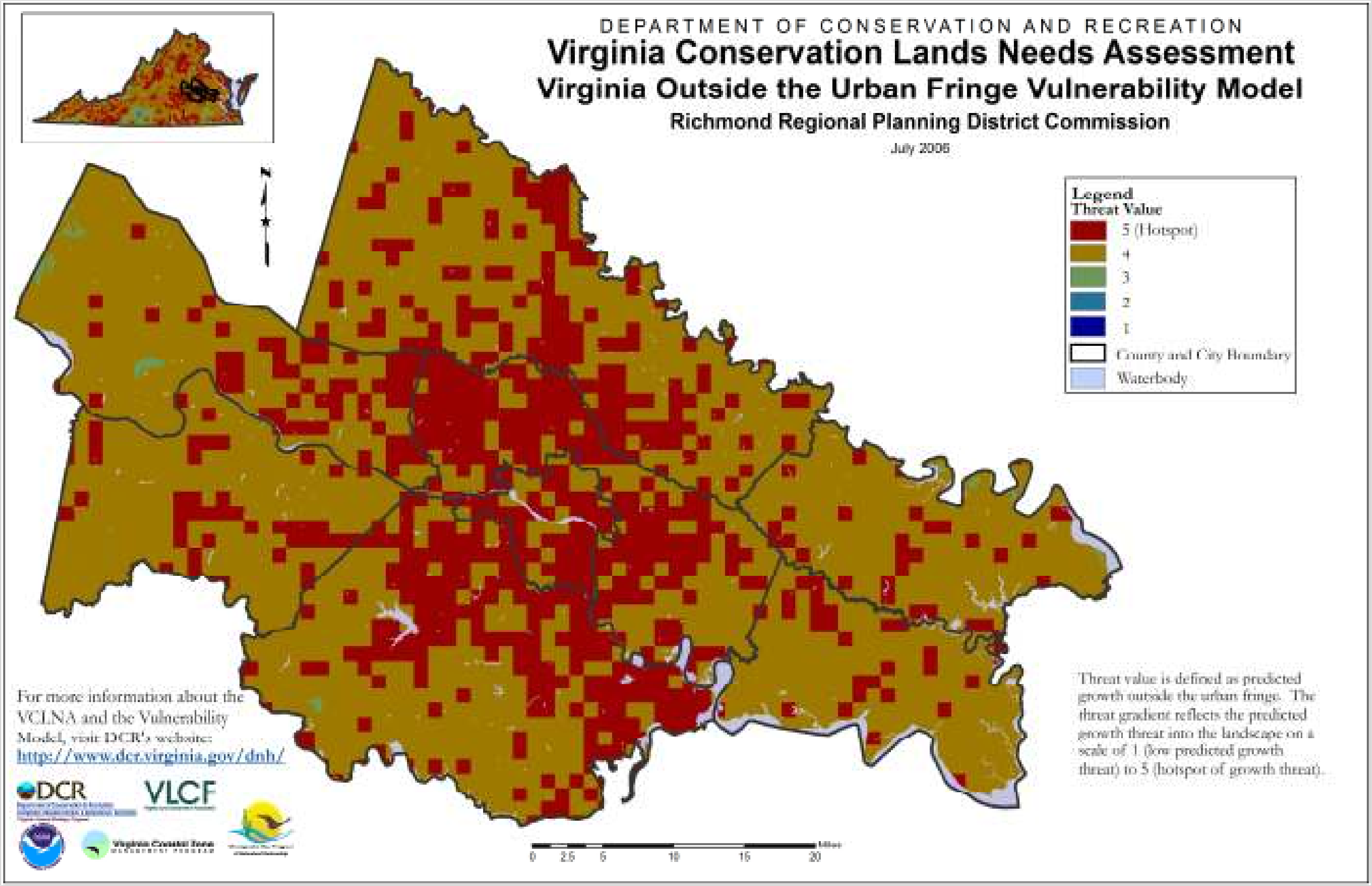

Figure 38. PDC 15 Richmond Regional Outside the Urban Fringe Vulnerability Model.

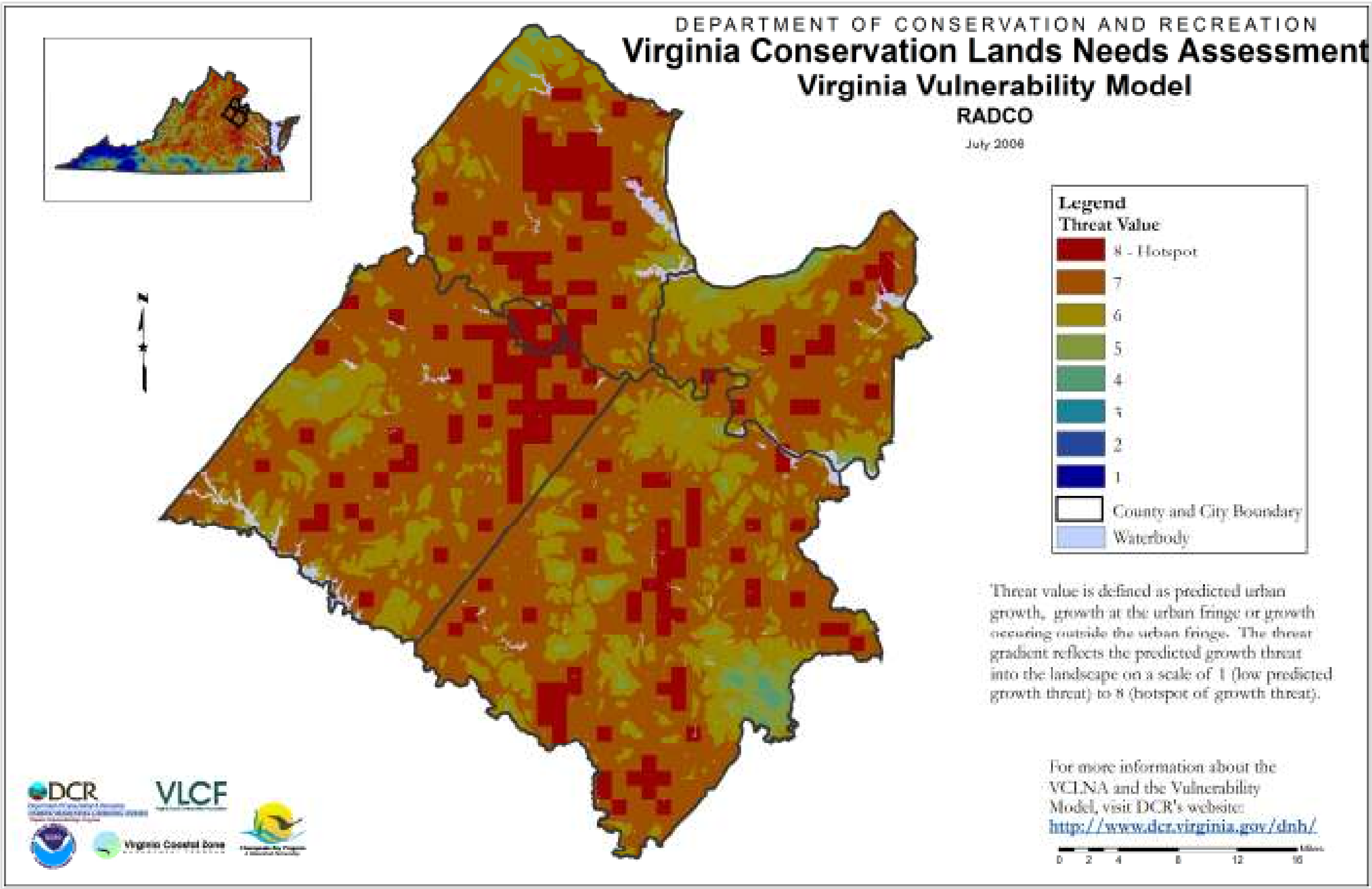

Figure 39. PDC 16 RADCO Vulnerability Model.

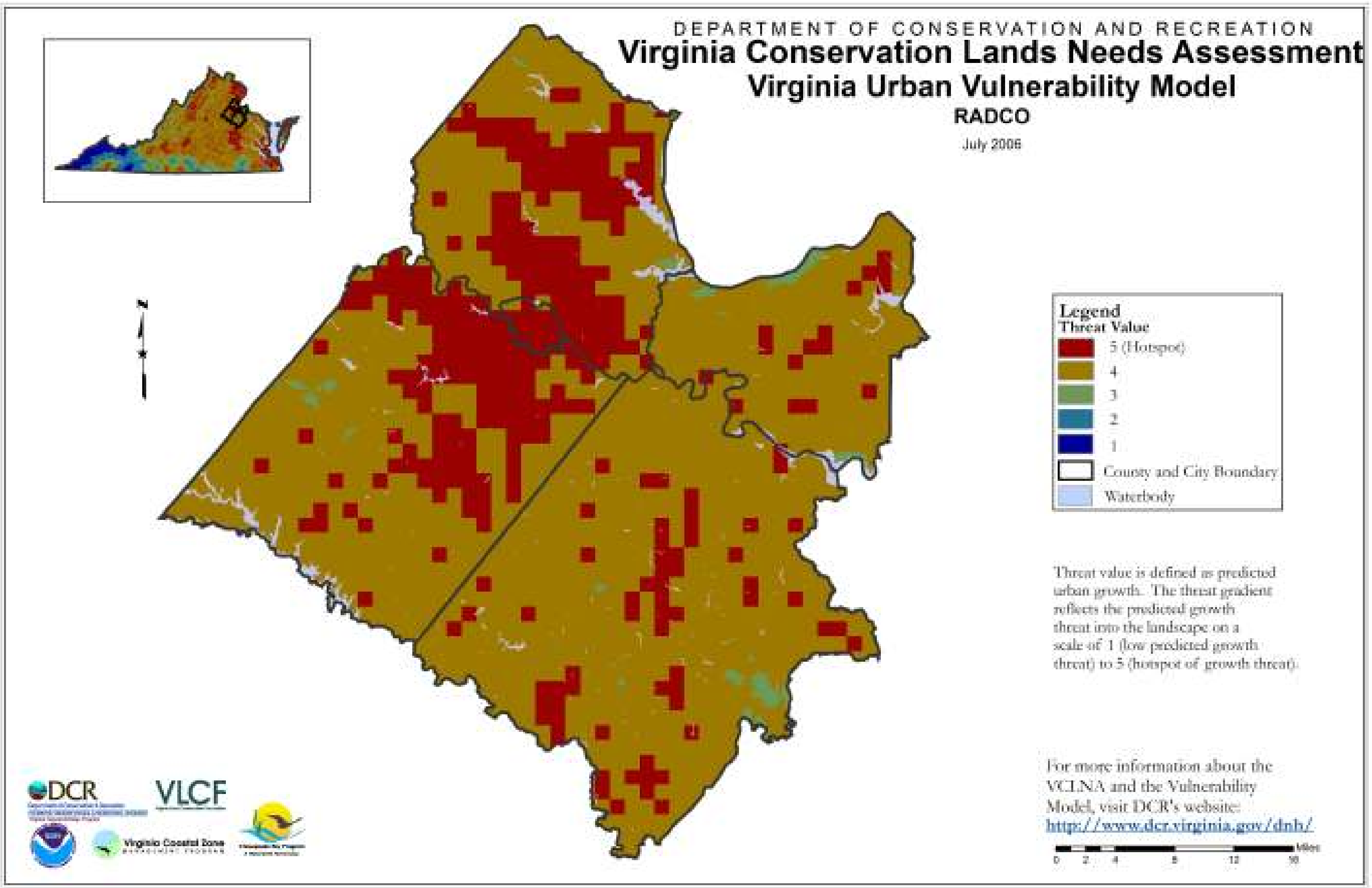

Figure 40. PDC 16 RADCO Urban Vulnerability Model.

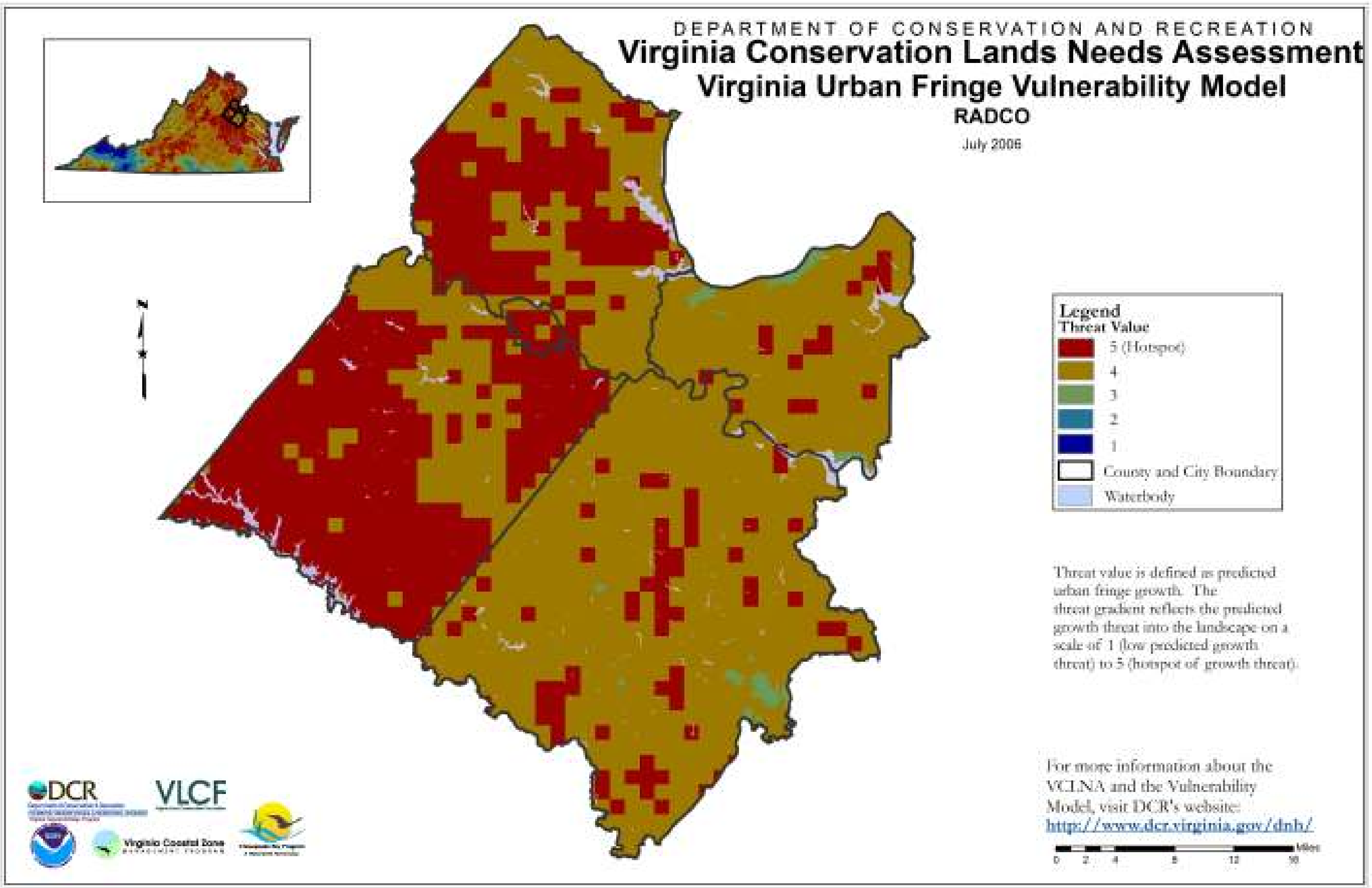

Figure 41. PDC 16 RADCO Urban Fringe Vulnerability Model.

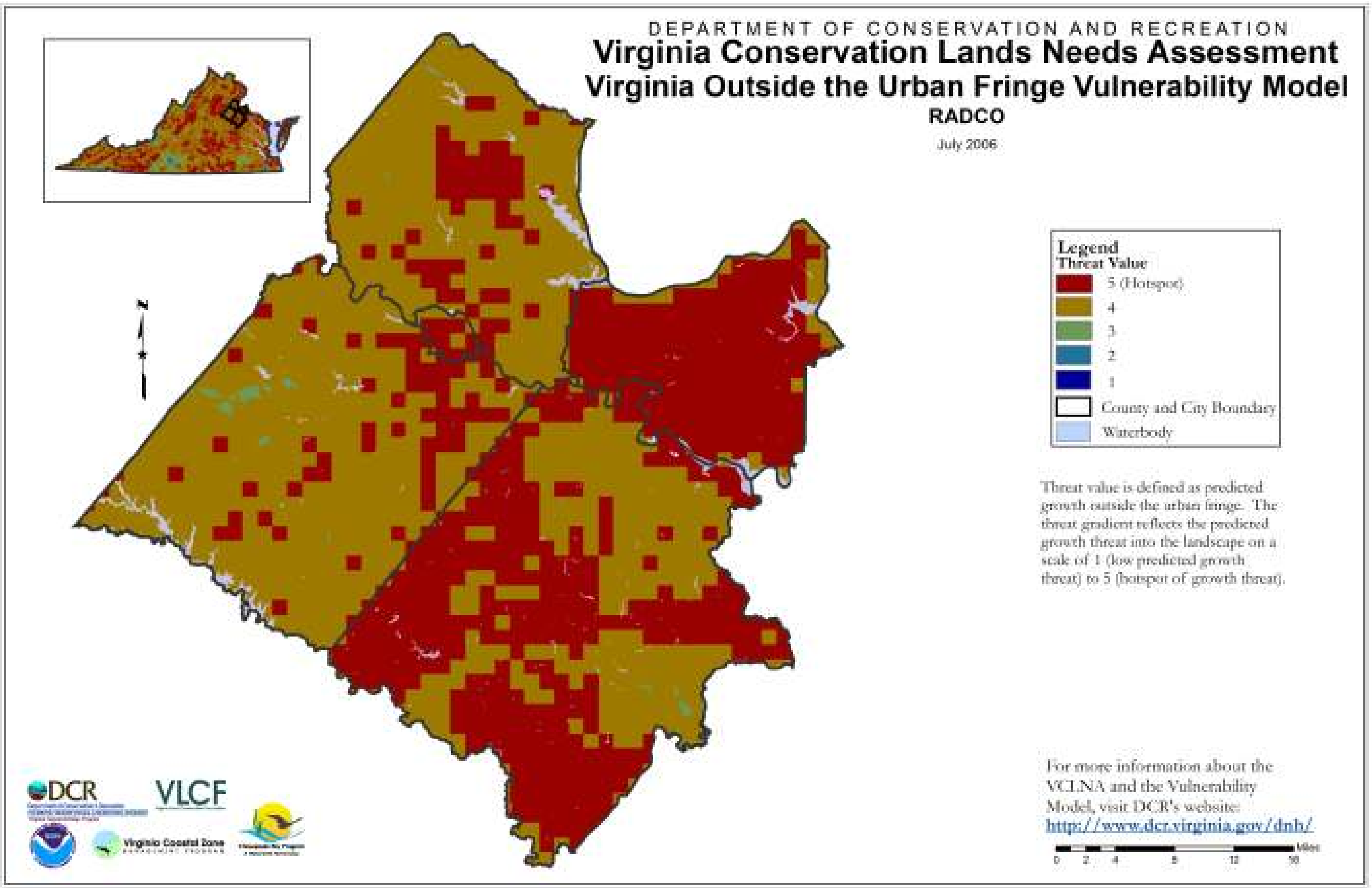

Figure 42. PDC 16 RADCO Outside the Urban Fringe Vulnerability Model.

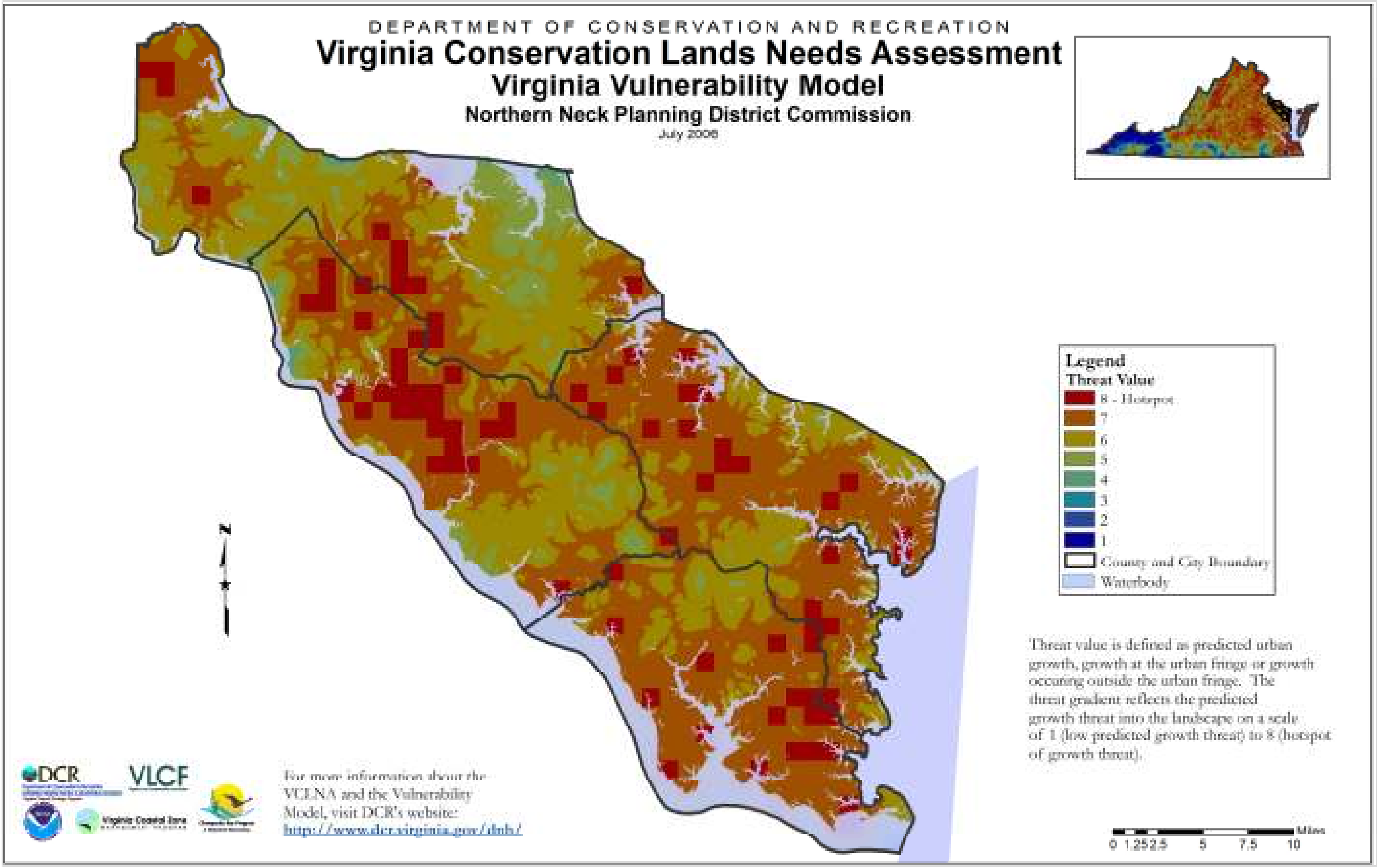

Figure 43. PDC 17 Northern Neck Vulnerability Model.

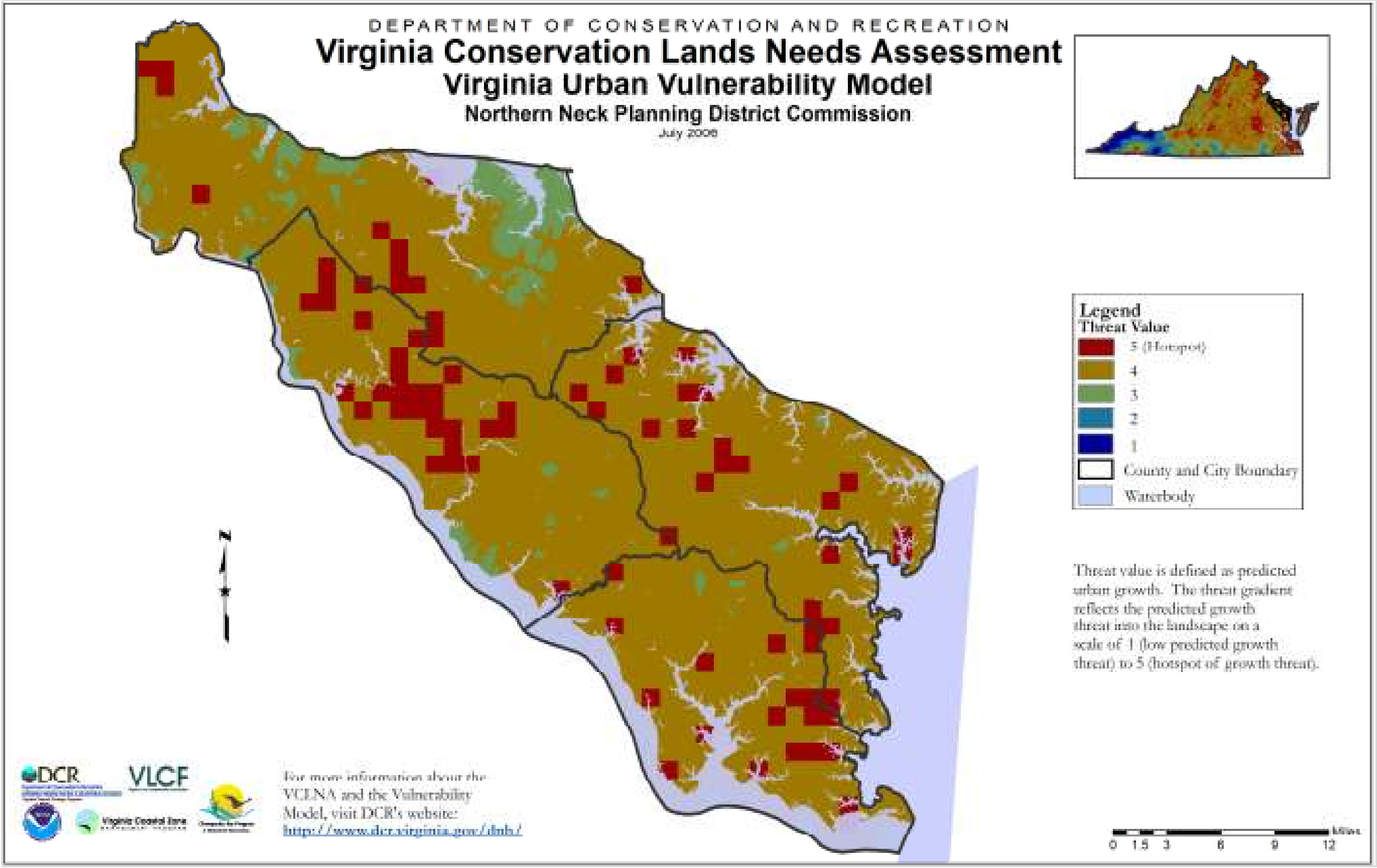

Figure 44. PDC 17 Northern Neck Urban Vulnerability Model.

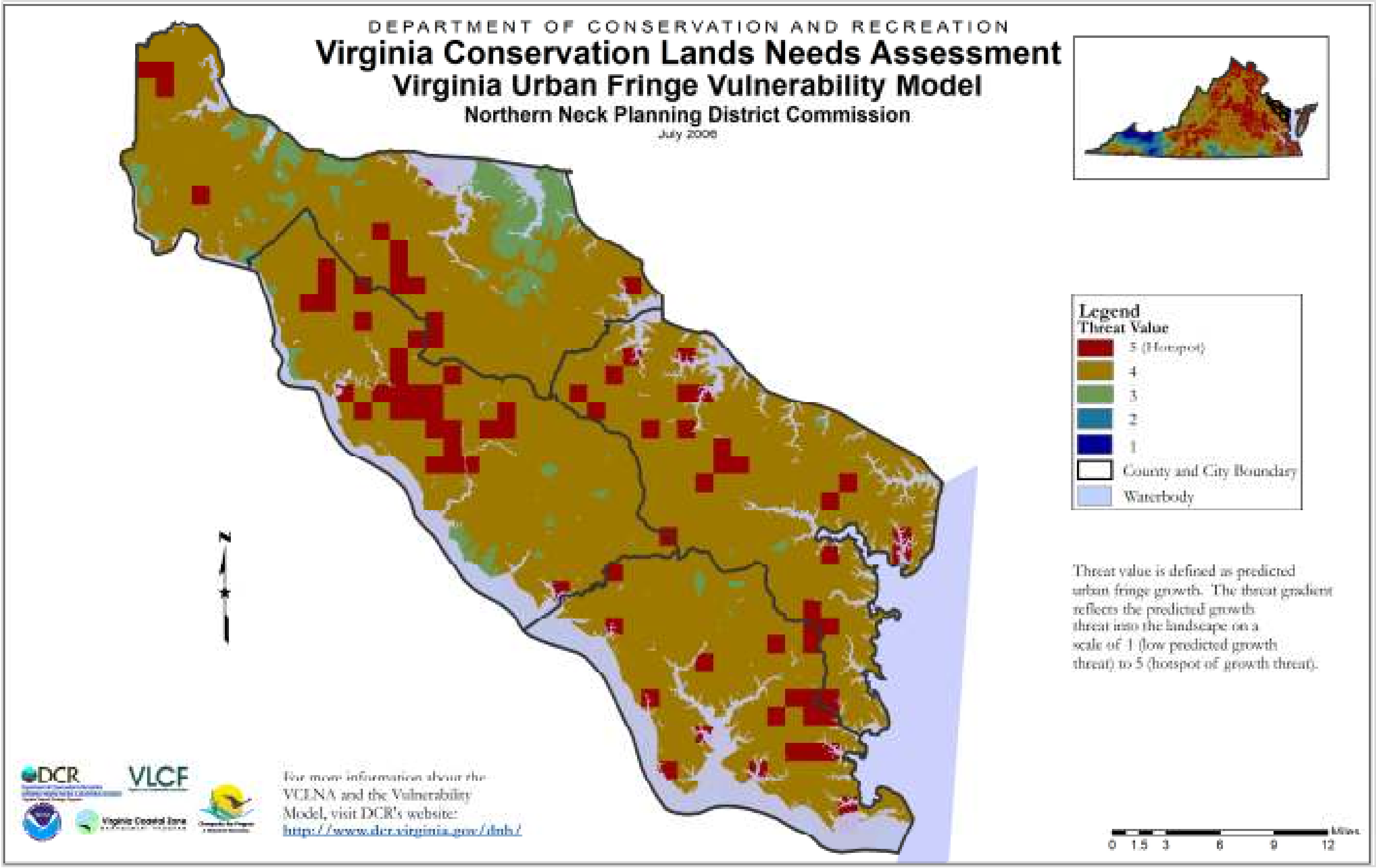

Figure 45. PDC 17 Northern Neck Urban Fringe Vulnerability Model.

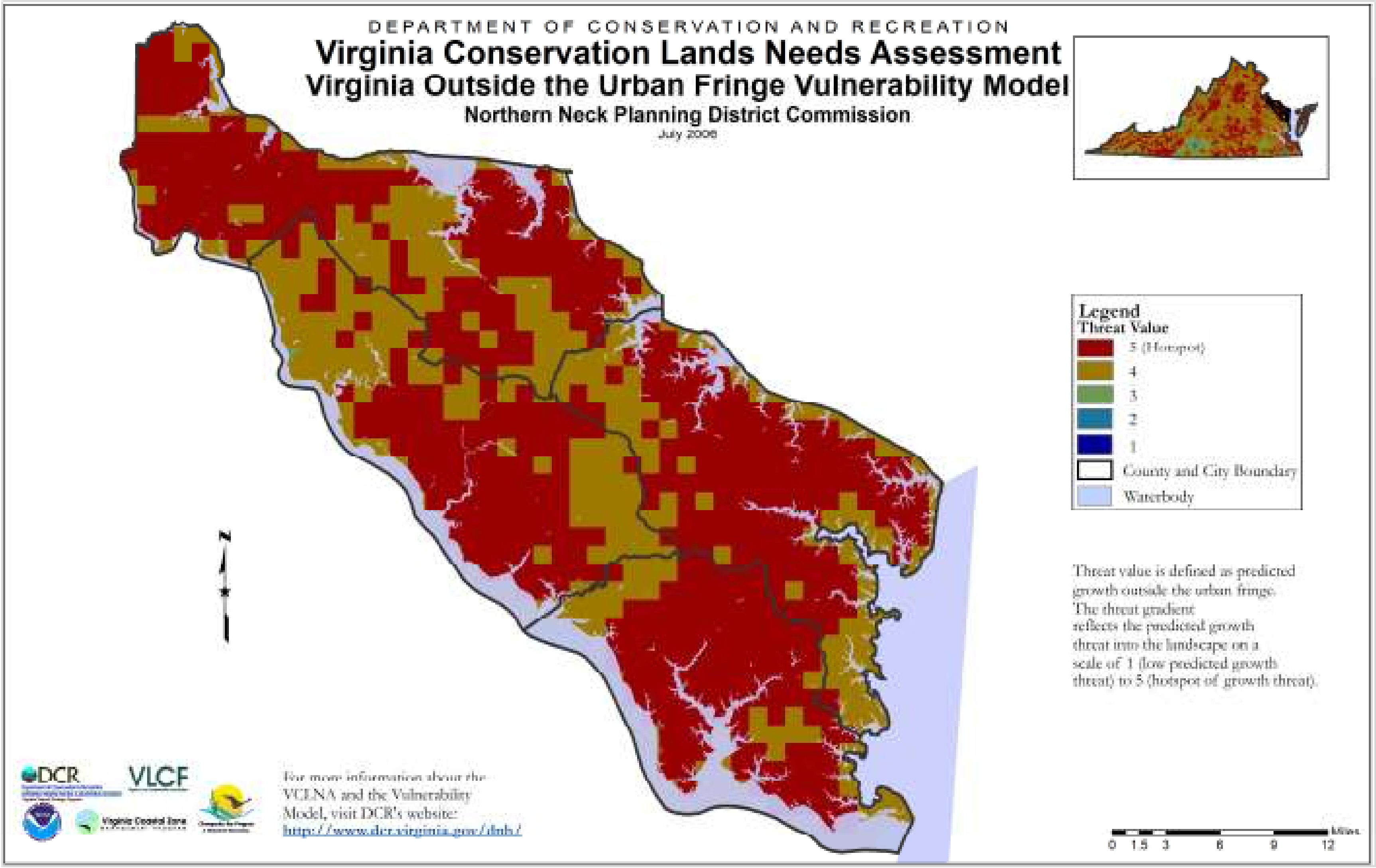

Figure 46. PDC 17 Northern Neck Outside the Urban Fringe Vulnerability Model.

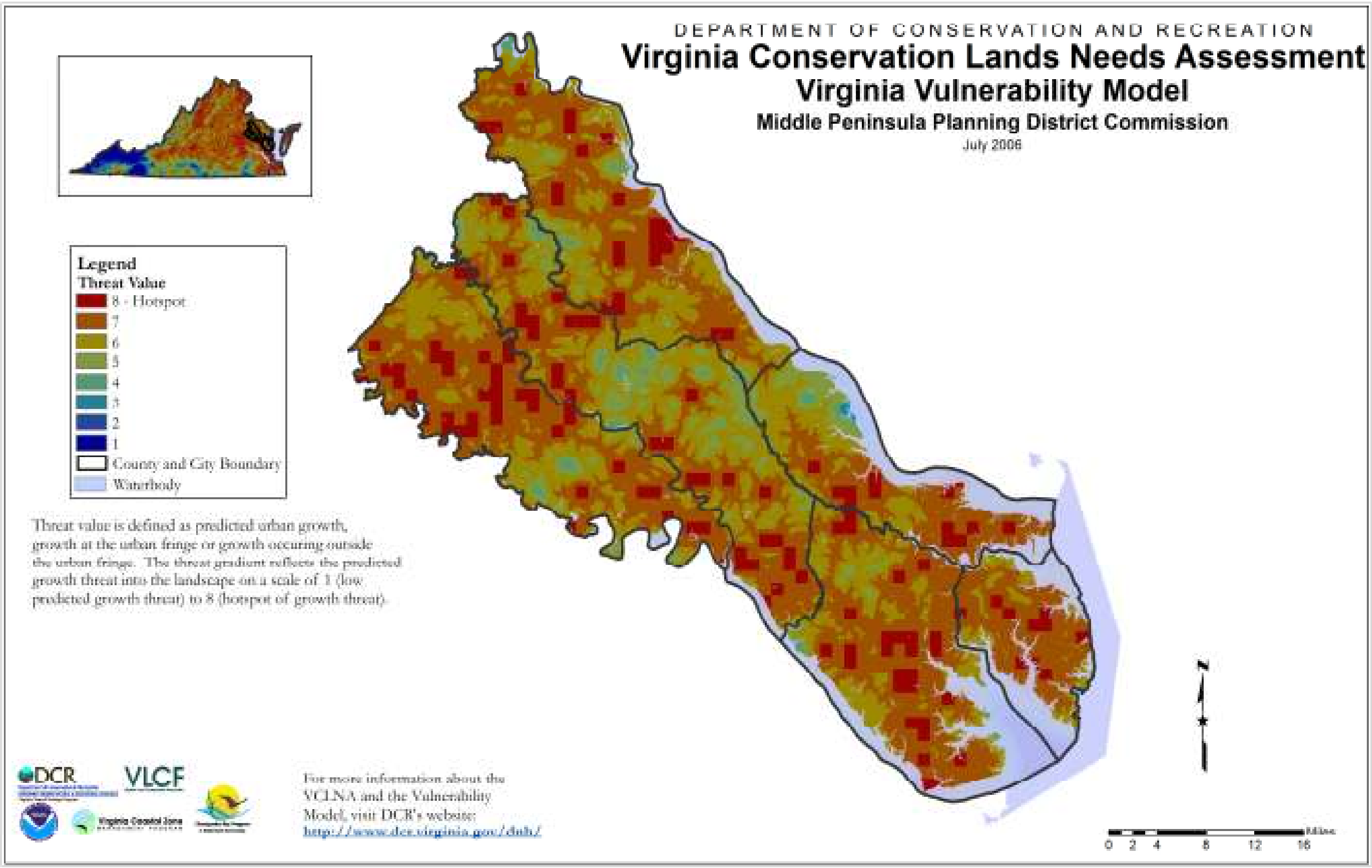

Figure 47. PDC 18 Middle Peninsula Vulnerability Model.

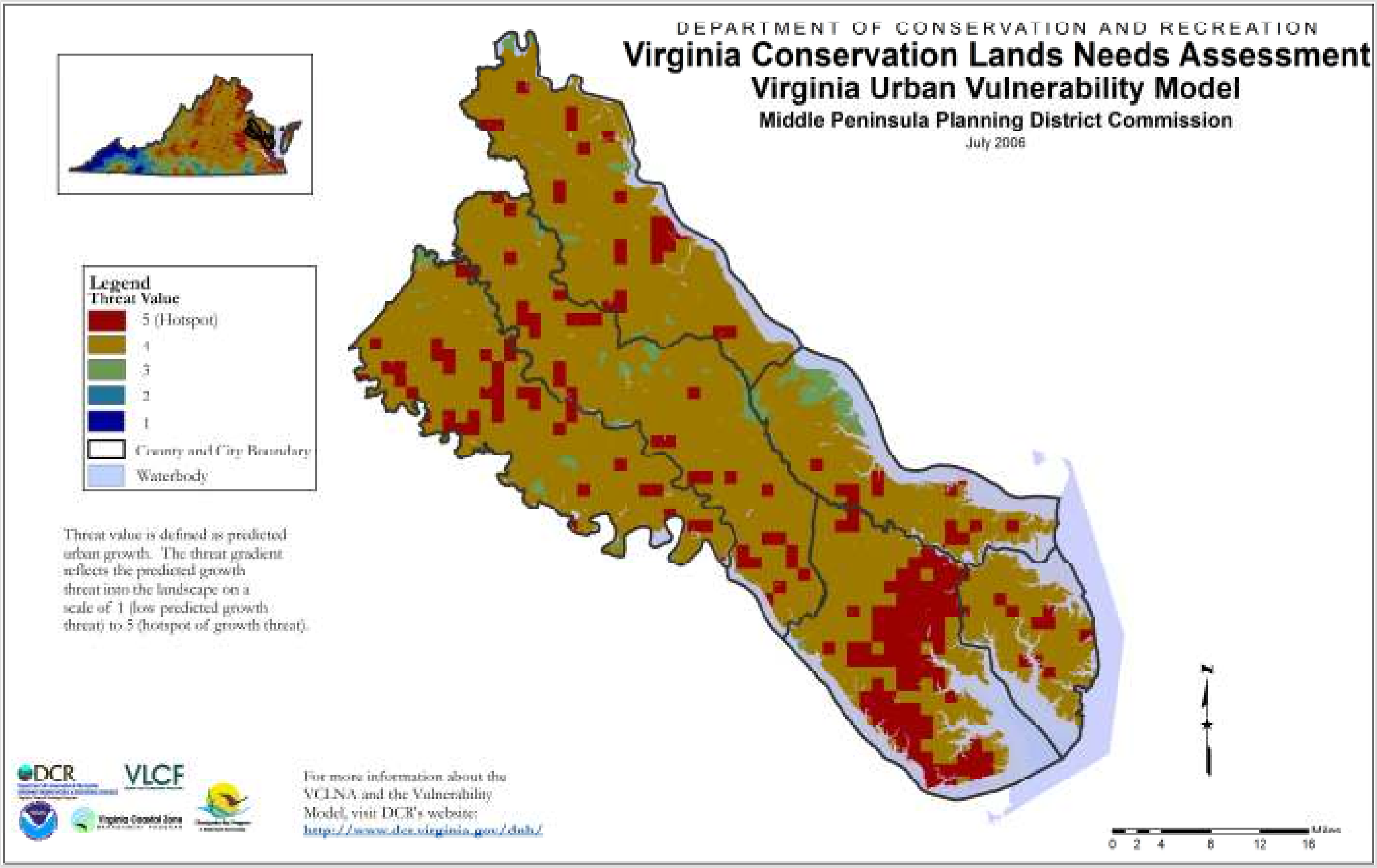

Figure 48. PDC 18 Middle Peninsula Urban Vulnerability Model.

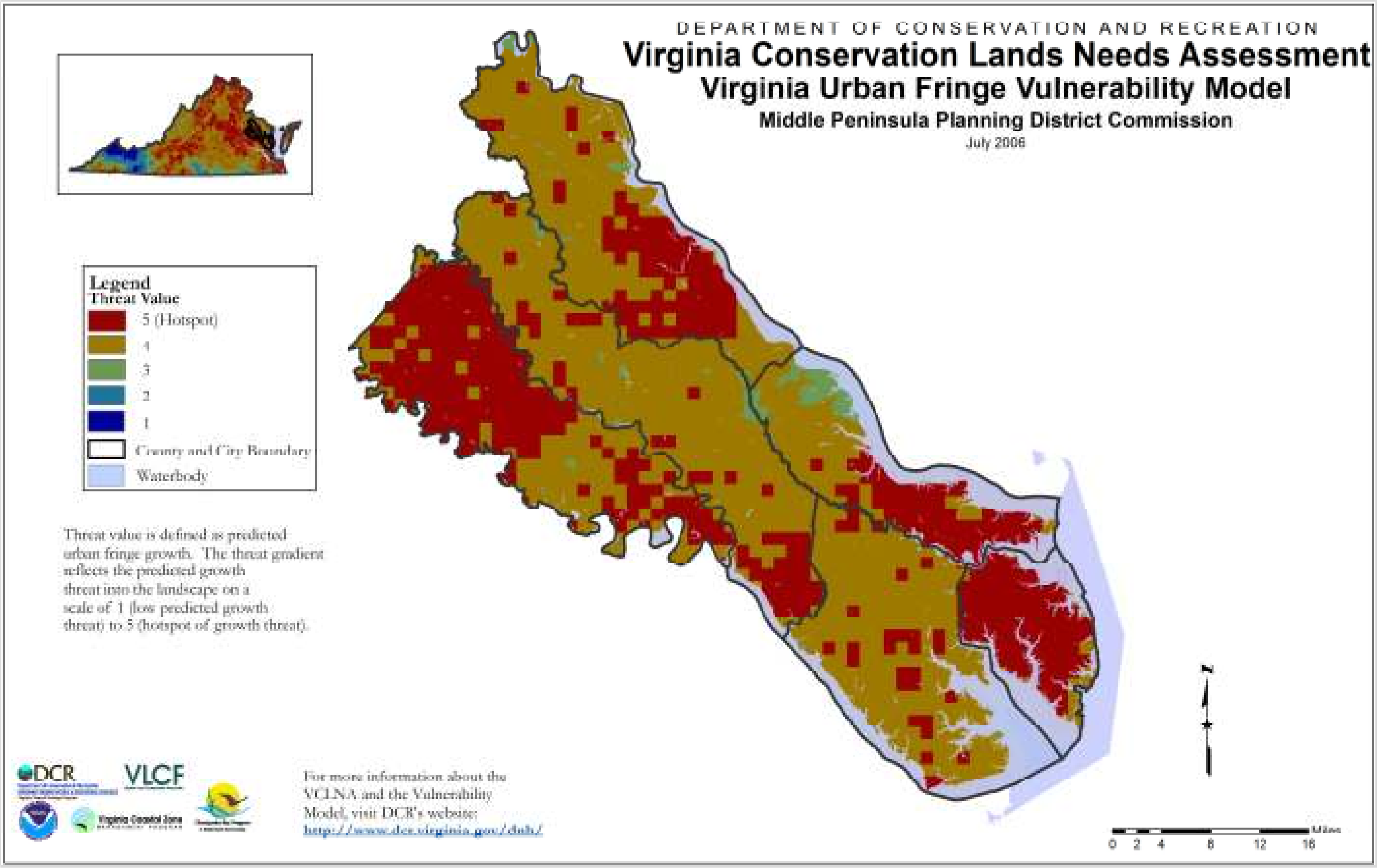

Figure 49. PDC 18 Middle Peninsula Urban Fringe Vulnerability Model.

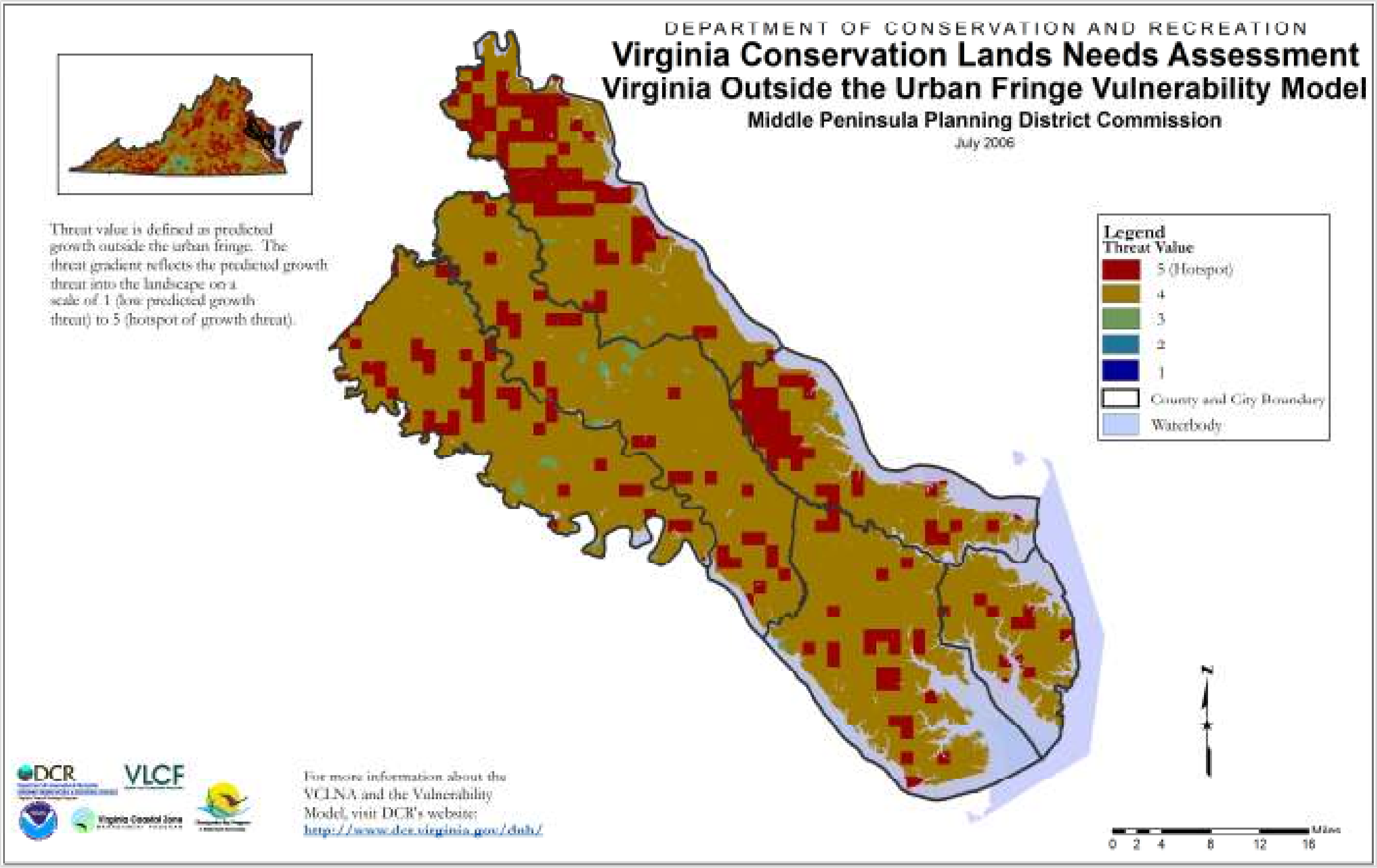

Figure 50. PDC 18 Middle Peninsula Outside the Urban Fringe Vulnerability Model.

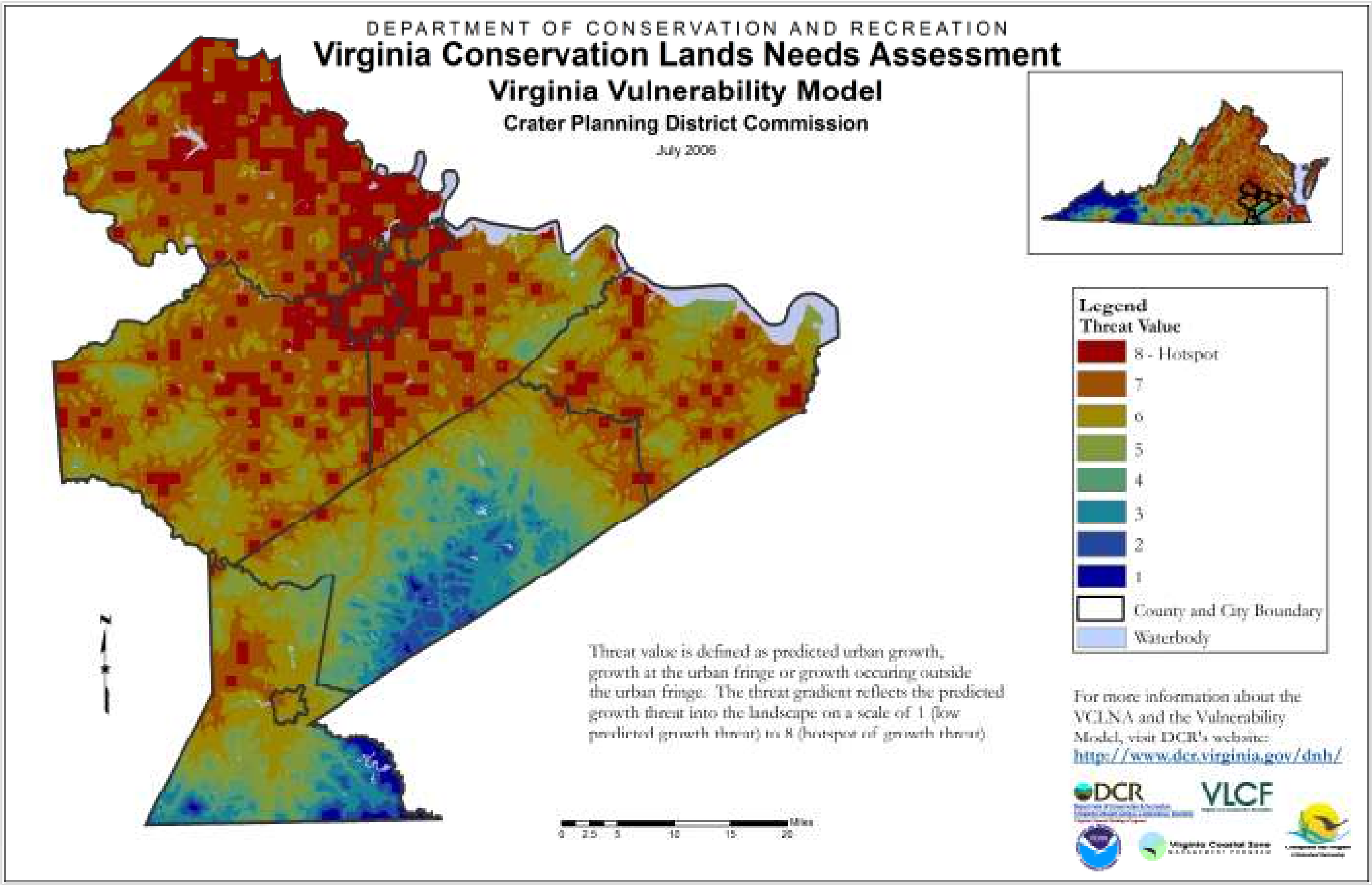

Figure 51. PDC 19 Crater Vulnerability Model.

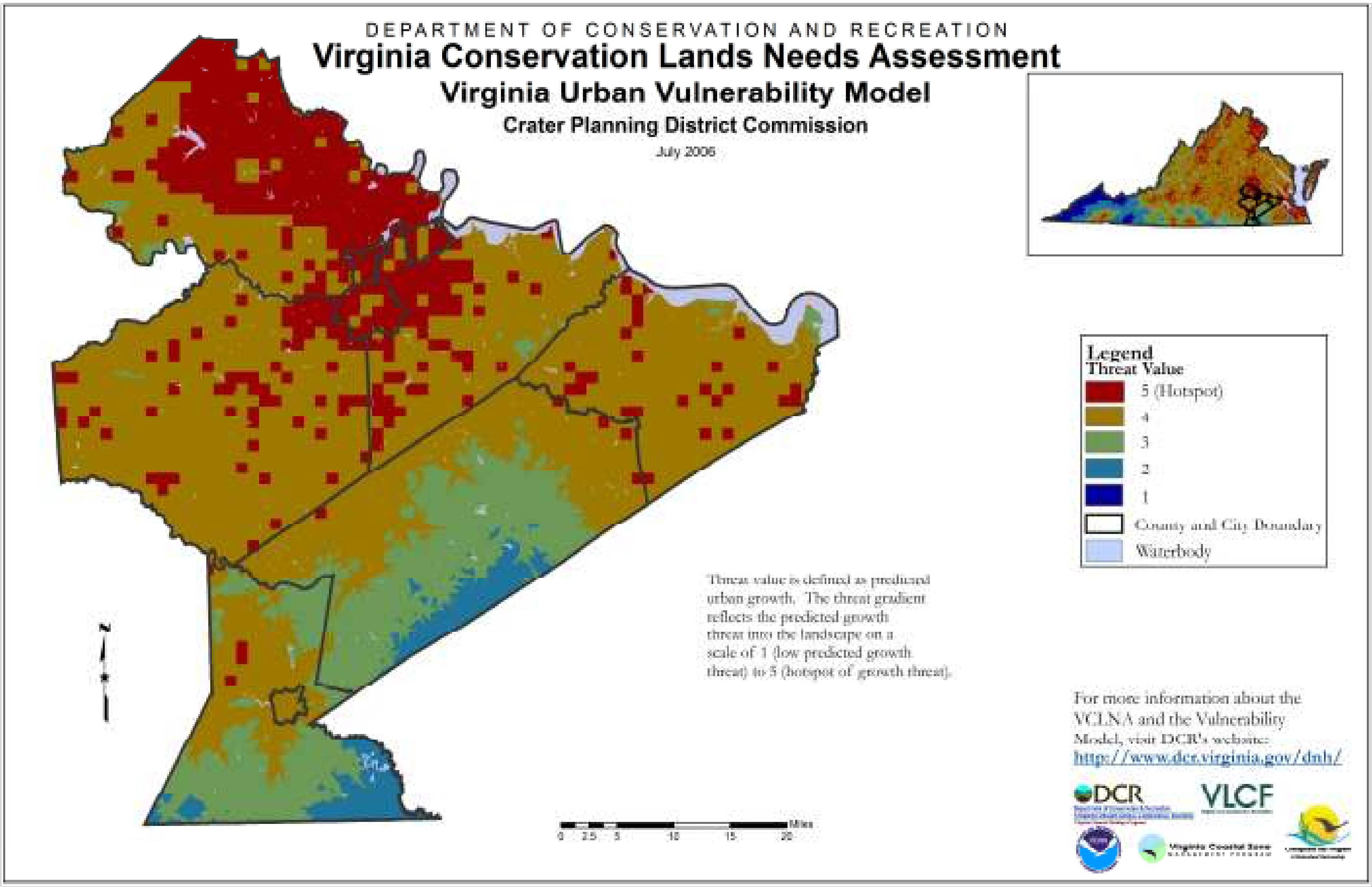

Figure 52. PDC 19 Crater Urban Vulnerability Model.

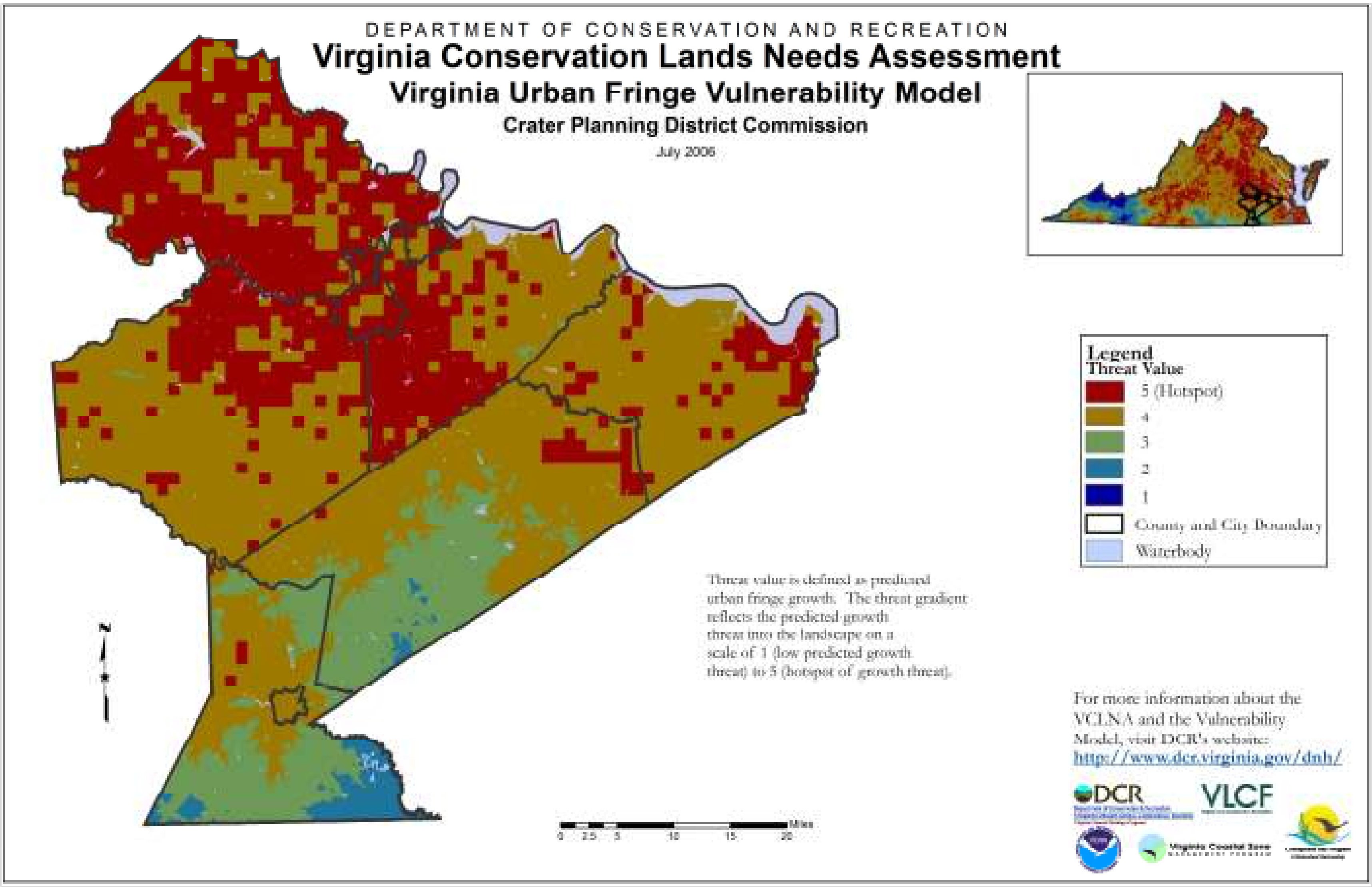

Figure 53. PDC 19 Crater Urban Fringe Vulnerability Model.

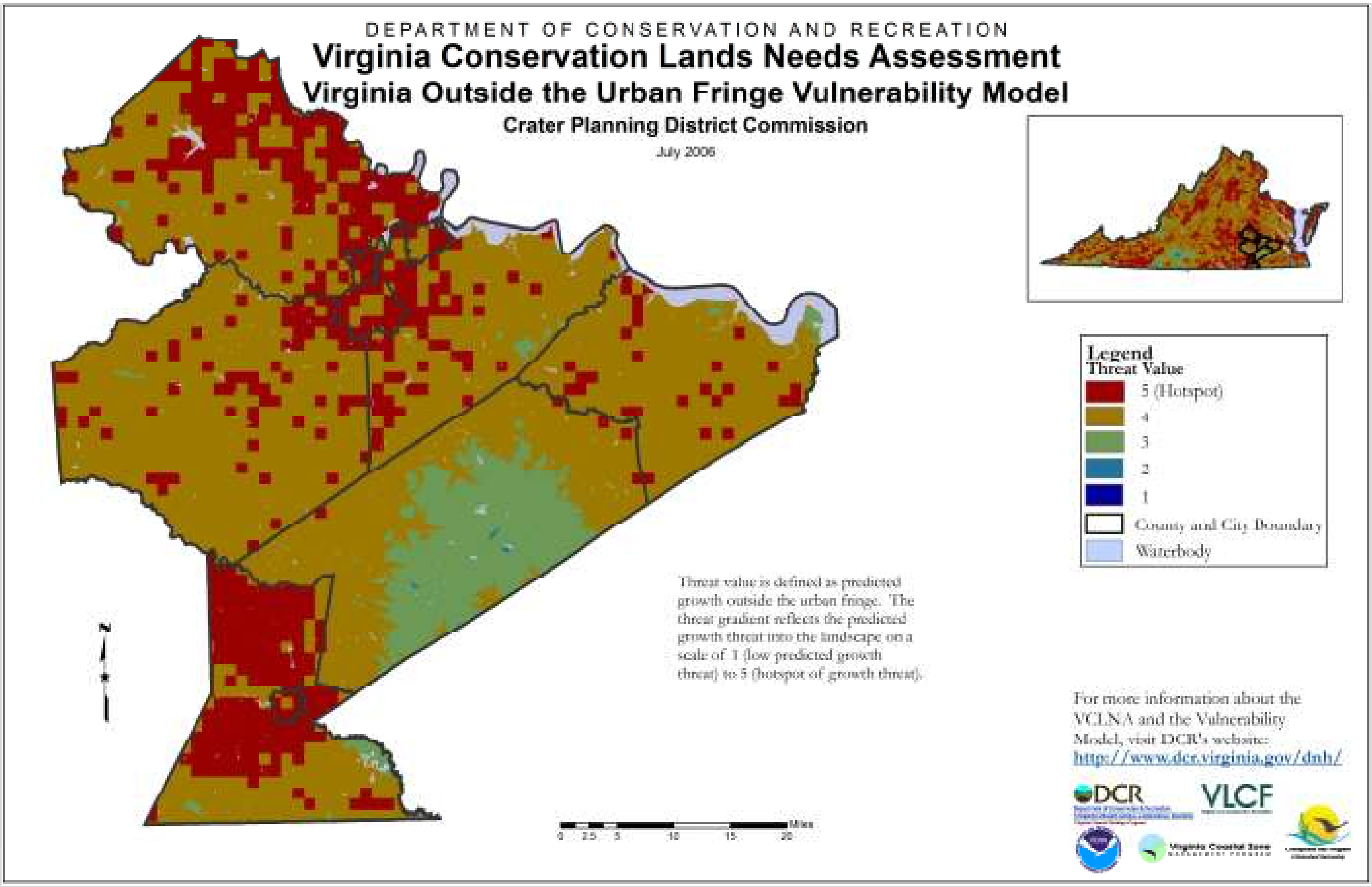

Figure 54. PDC 19 Crater Outside the Urban Fringe Vulnerability Model.

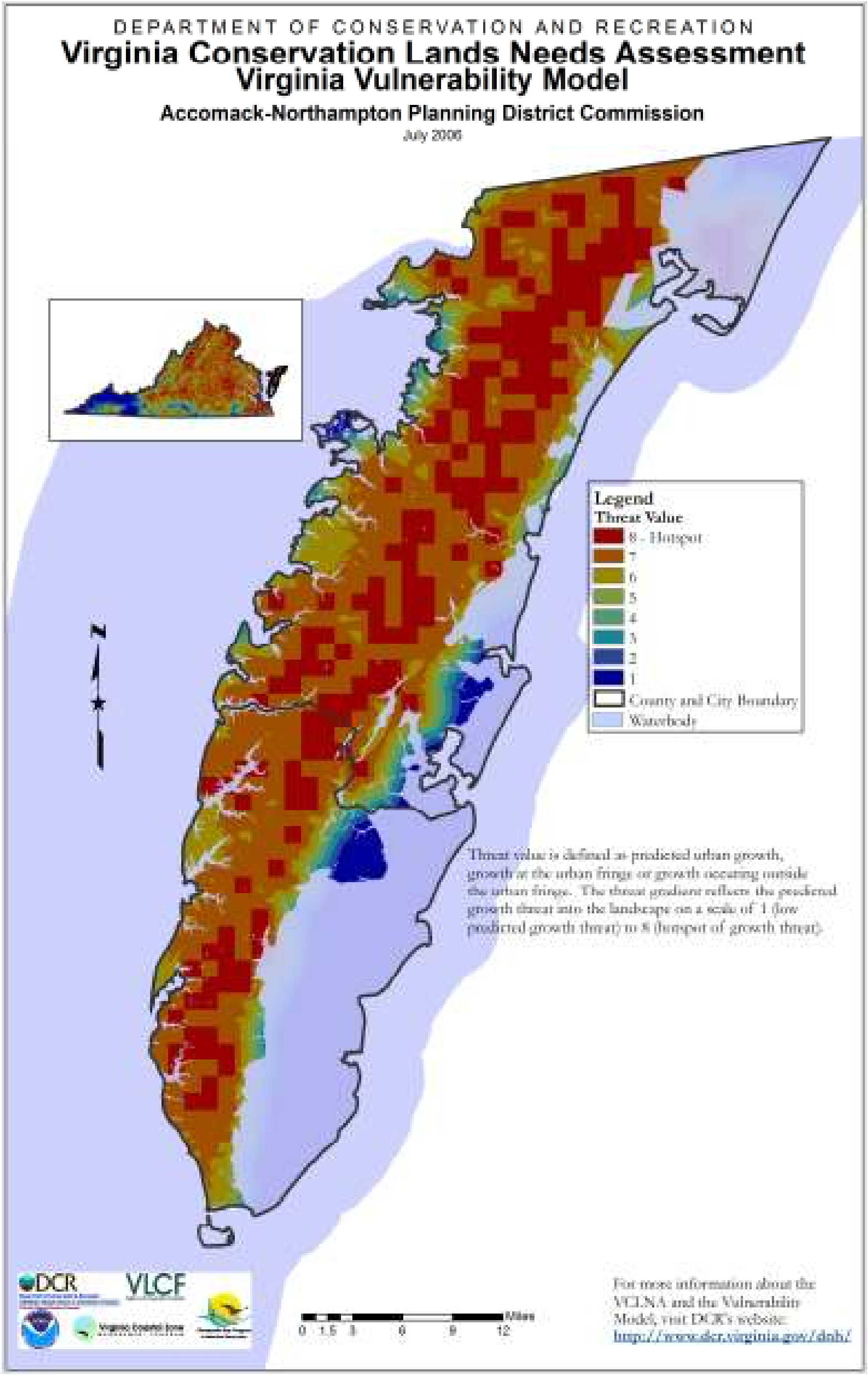

Figure 55. PDC 22 Accomack-Northampton Planning District Commission Vulnerability Model.

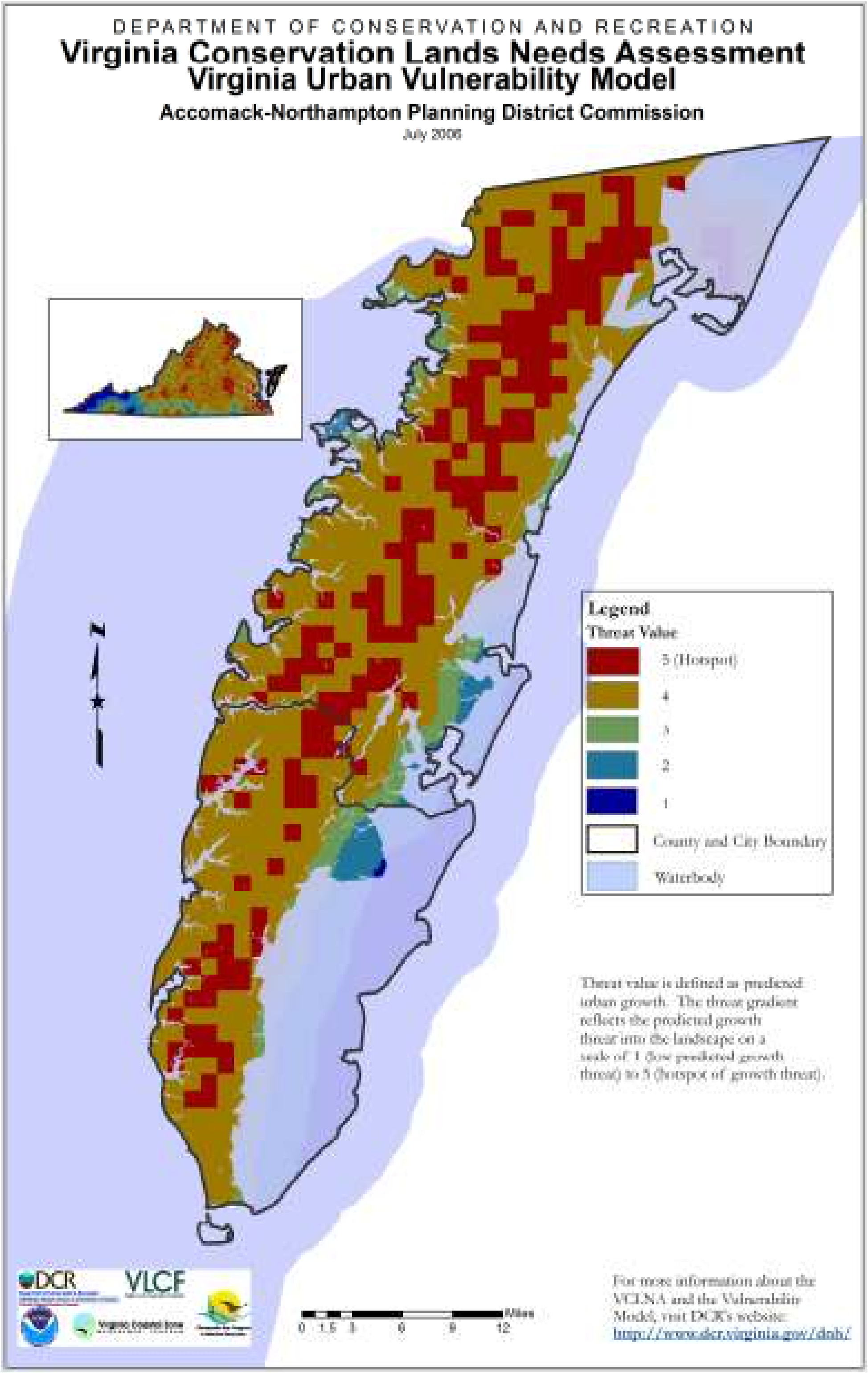

Figure 56. PDC 22 Accomack-Northampton Planning District Commission Urban Vulnerability Model.

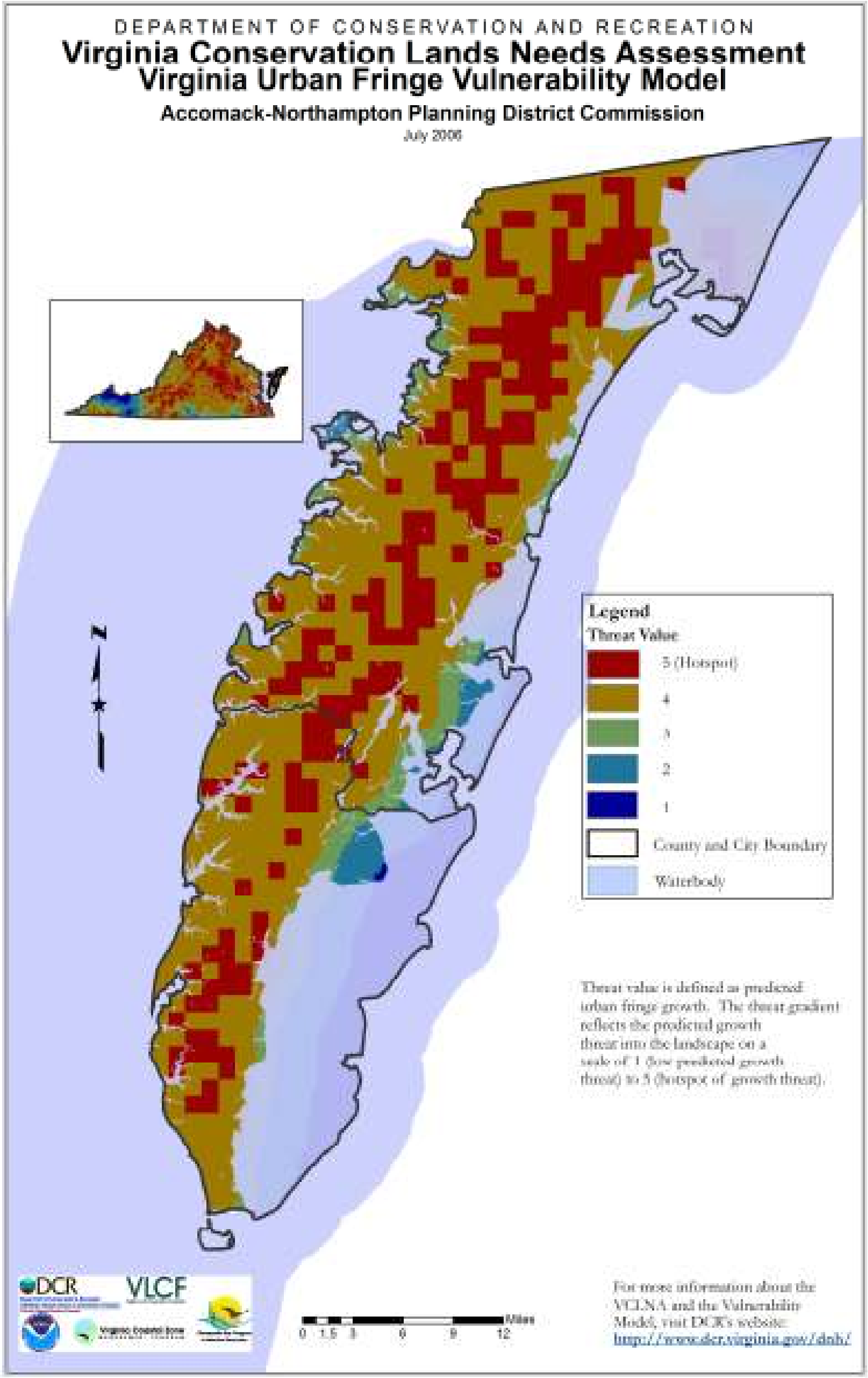

Figure 57. PDC 22 Accomack-Northampton Planning District Commission Urban Fringe Vulnerability Model.

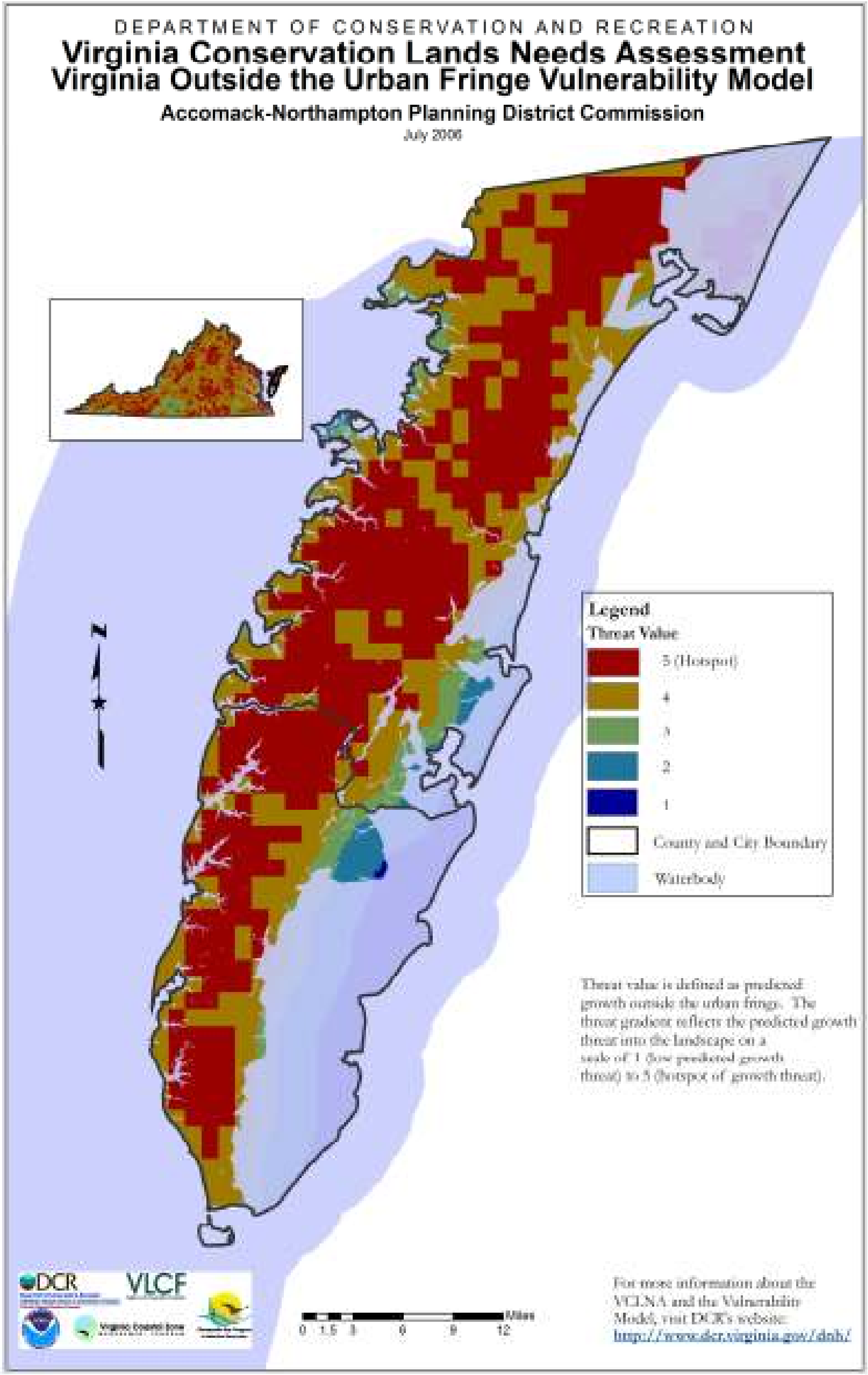

Figure 58. PDC 22 Accomack-Northampton Planning District Commission Outside the Urban Fringe Vulnerability Model

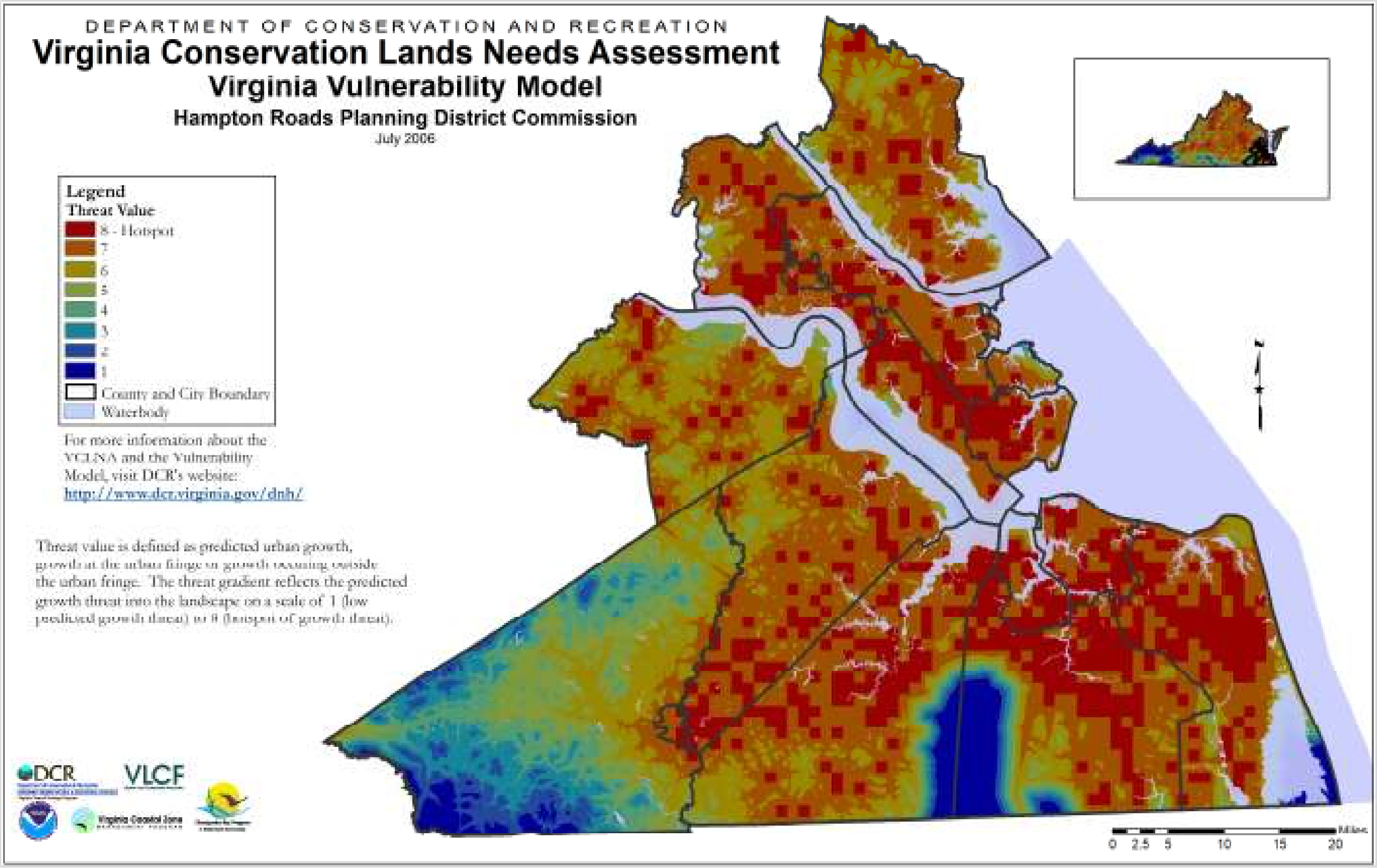

Figure 59. PDC 23 Hampton Roads Planning District Commission Vulnerability Model

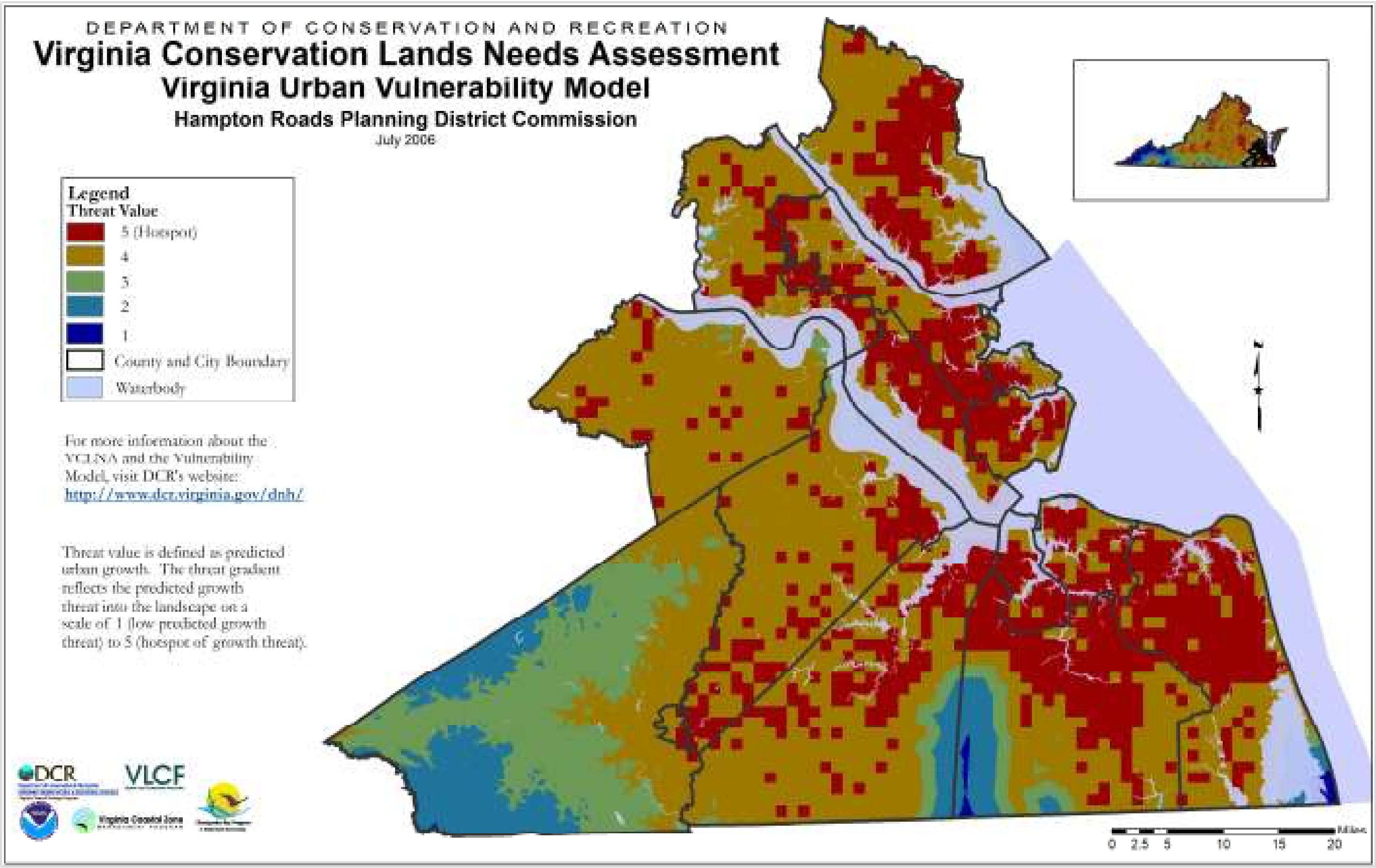

Figure 60. PDC 23 Hampton Roads Planning District Commission Urban Vulnerability Model

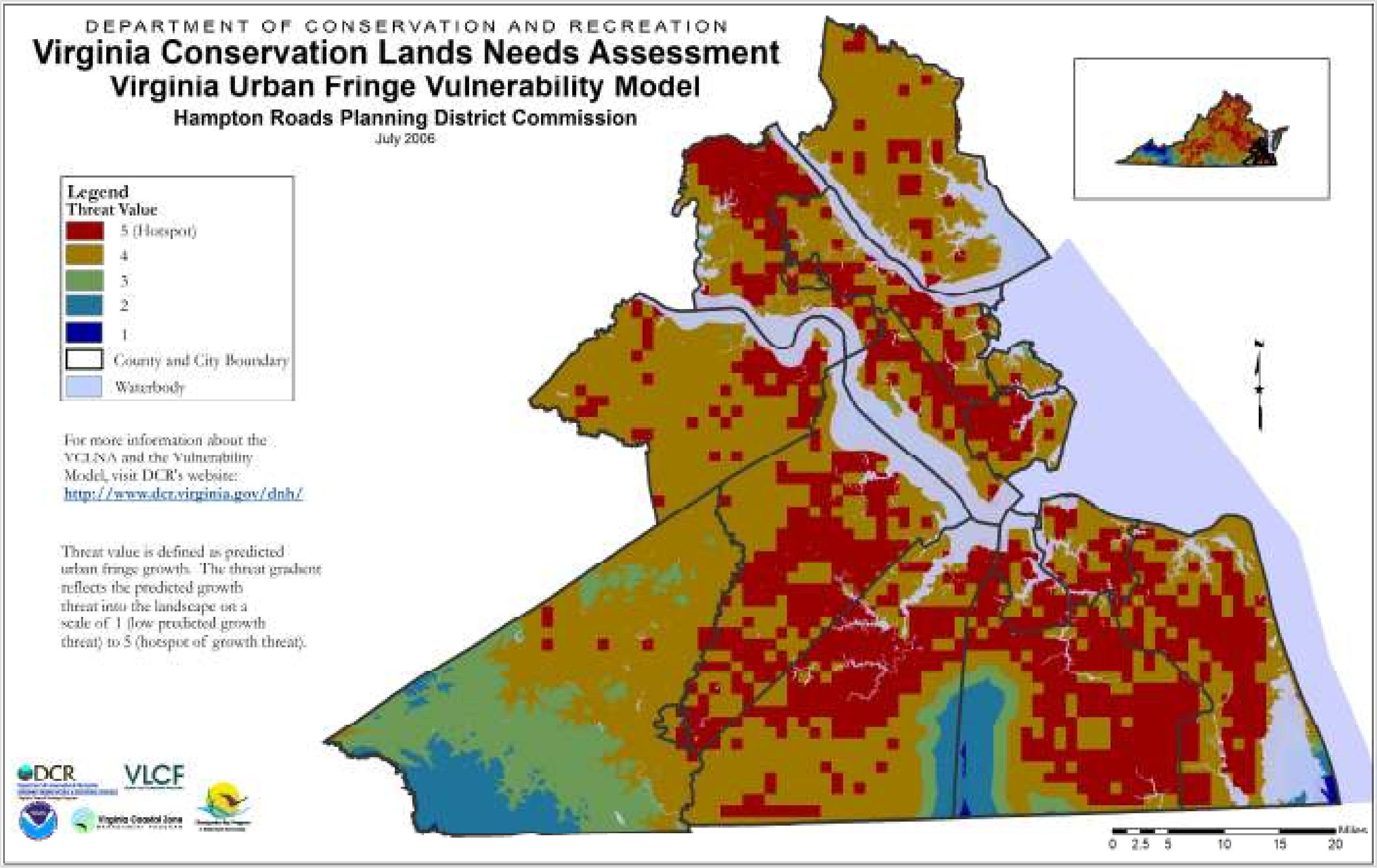

Figure 61. PDC 23 Hampton Roads Planning District Commission Urban Fringe Vulnerability Model

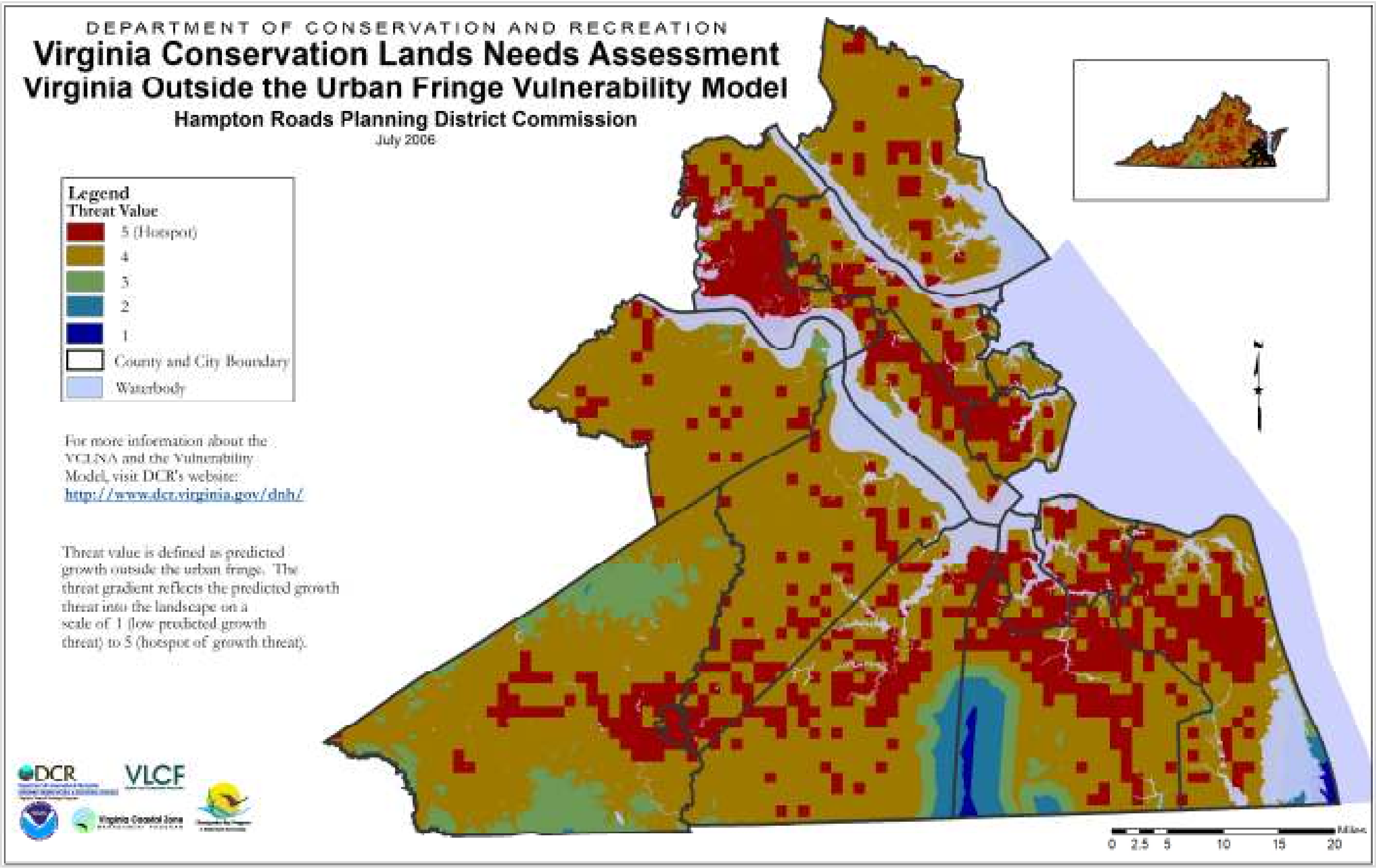

Figure 62. PDC 23 Hampton Roads Planning District Commission Outside the Urban Fringe Vulnerability Model

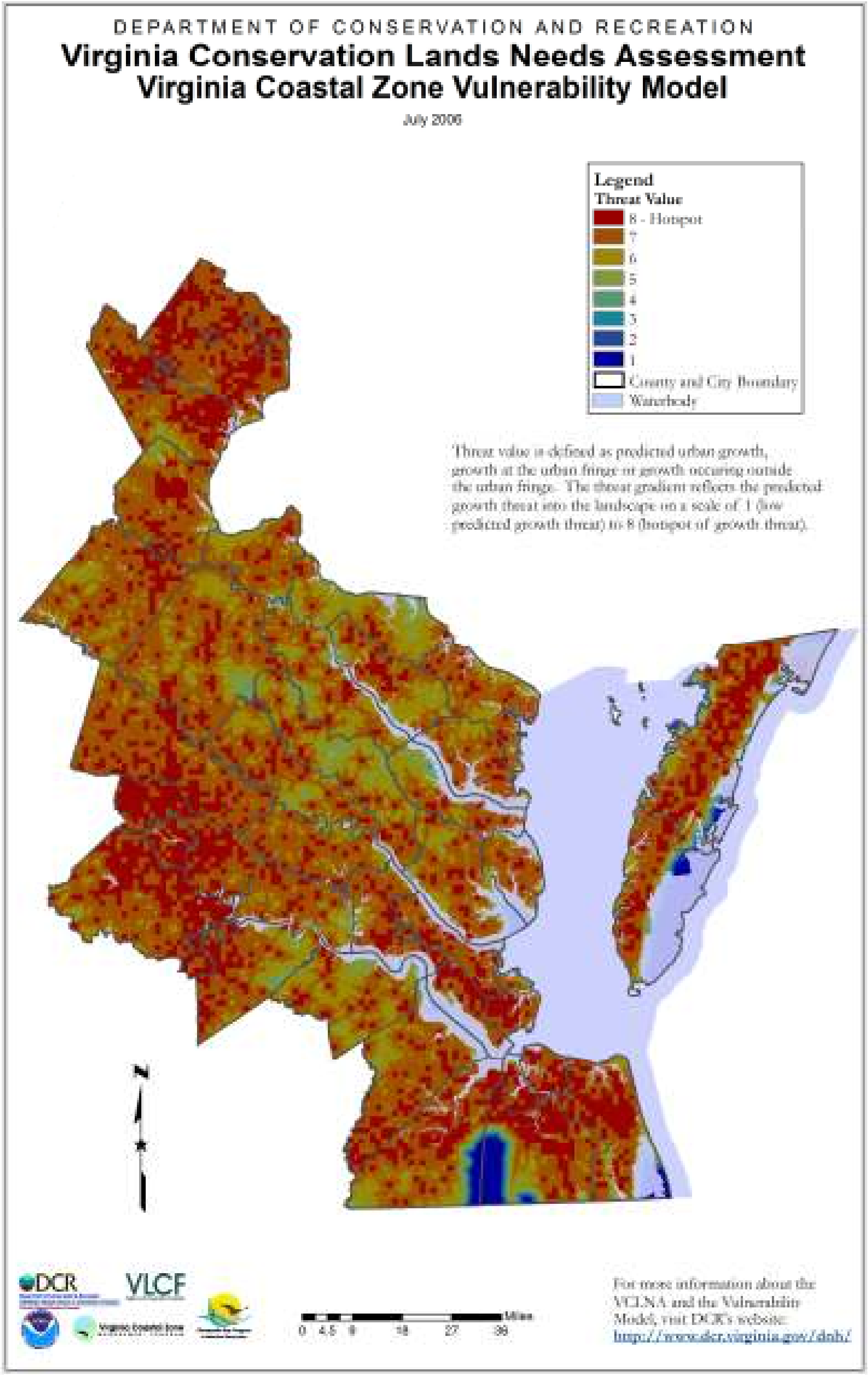

Figure 63. Coastal Zone Vulnerability Model.

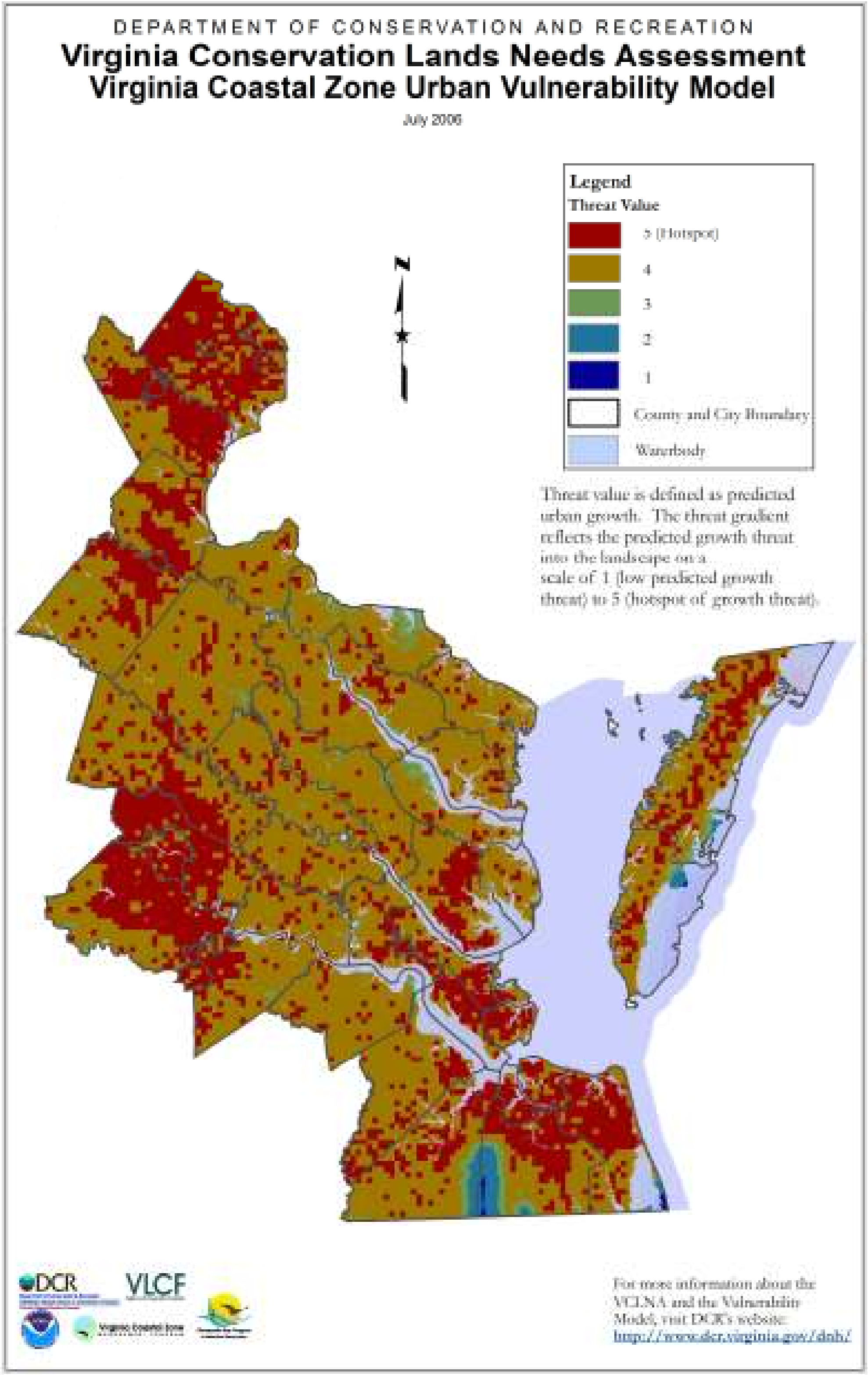

Figure 64. Coastal Zone Urban Vulnerability Model.

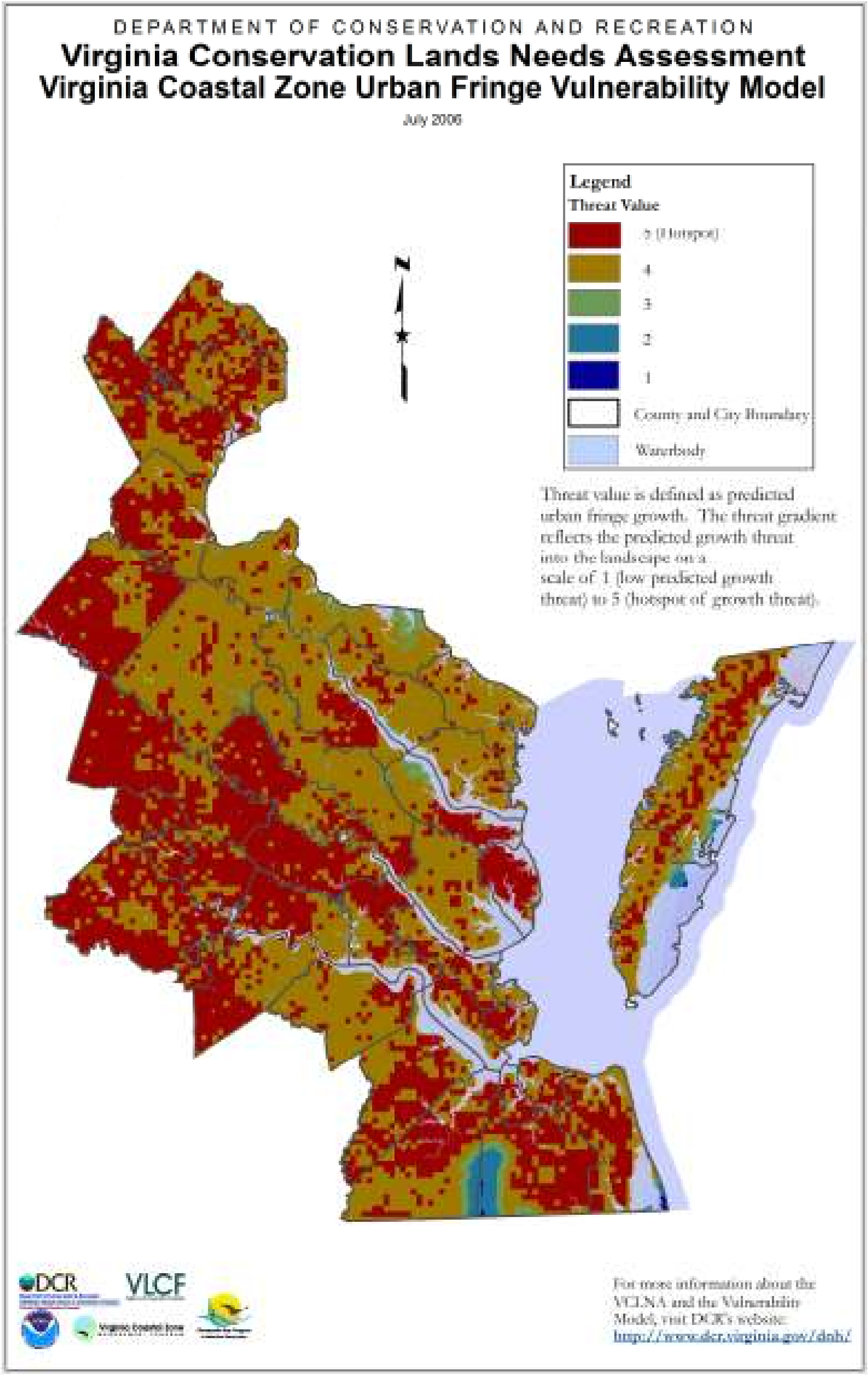

Figure 65. Coastal Zone Urban Fringe Vulnerability Model.

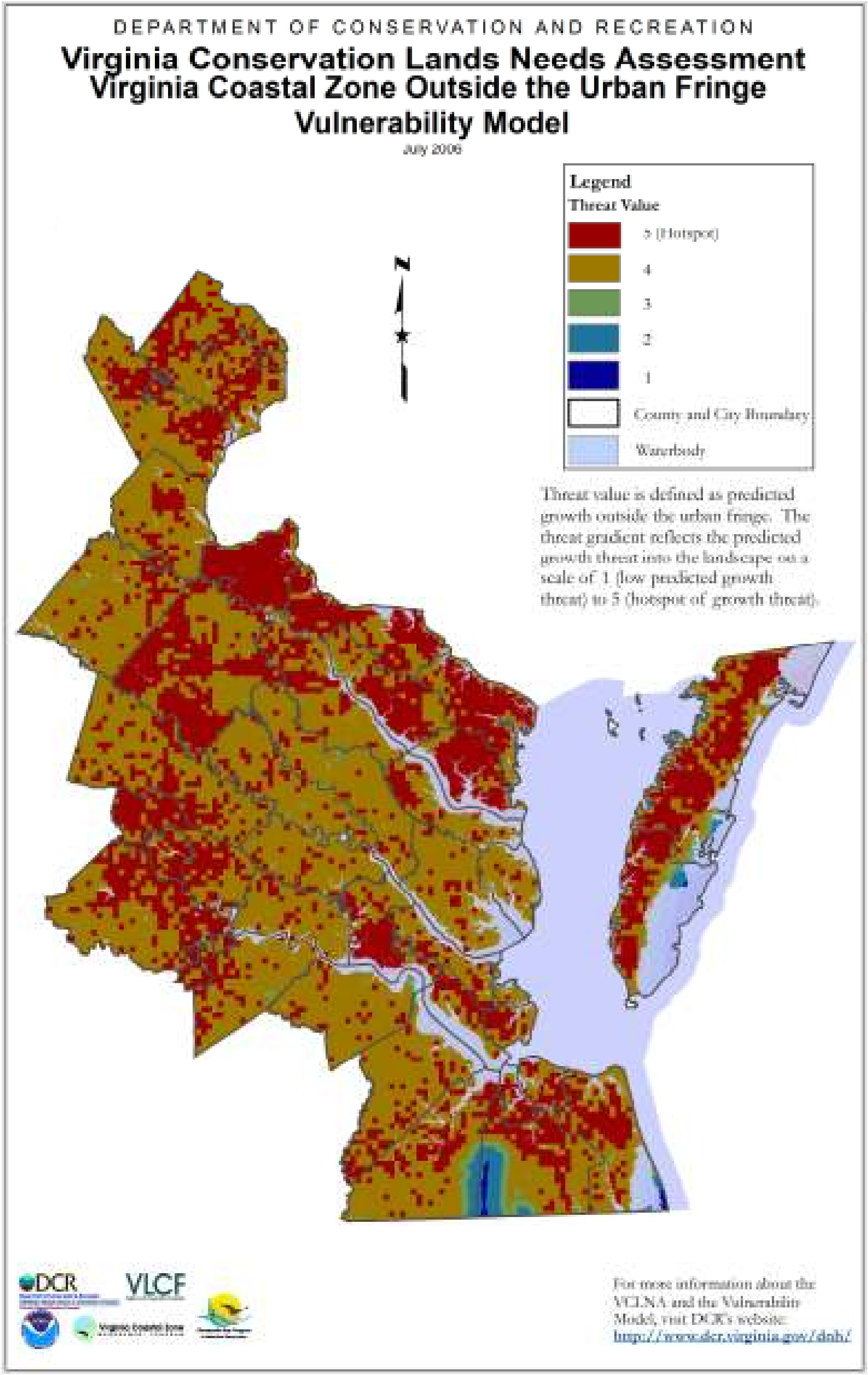

Figure 66. Coastal Zone Outside the Urban Fringe Vulnerability Model.

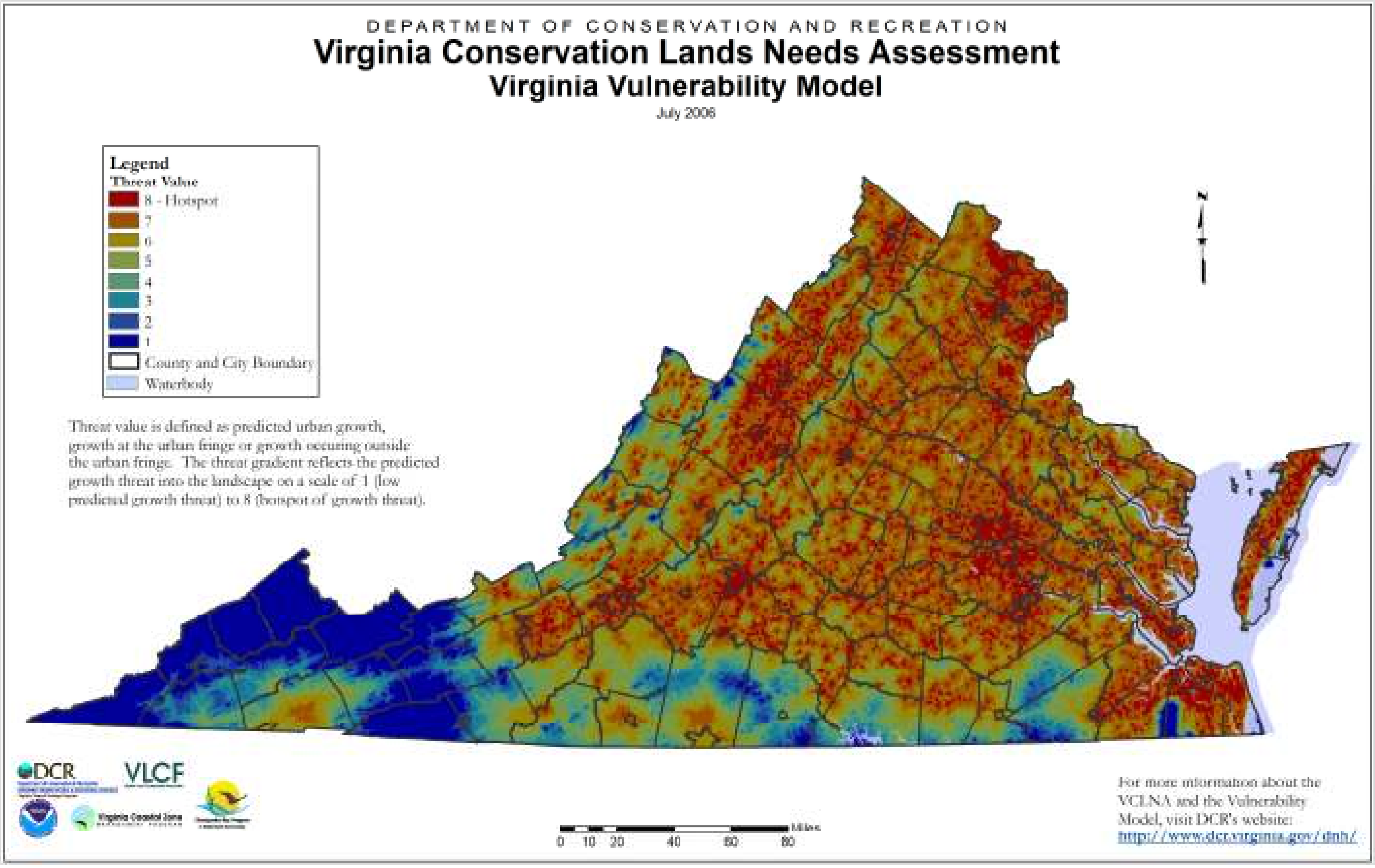

Figure 67. Virginia Vulnerability Model.

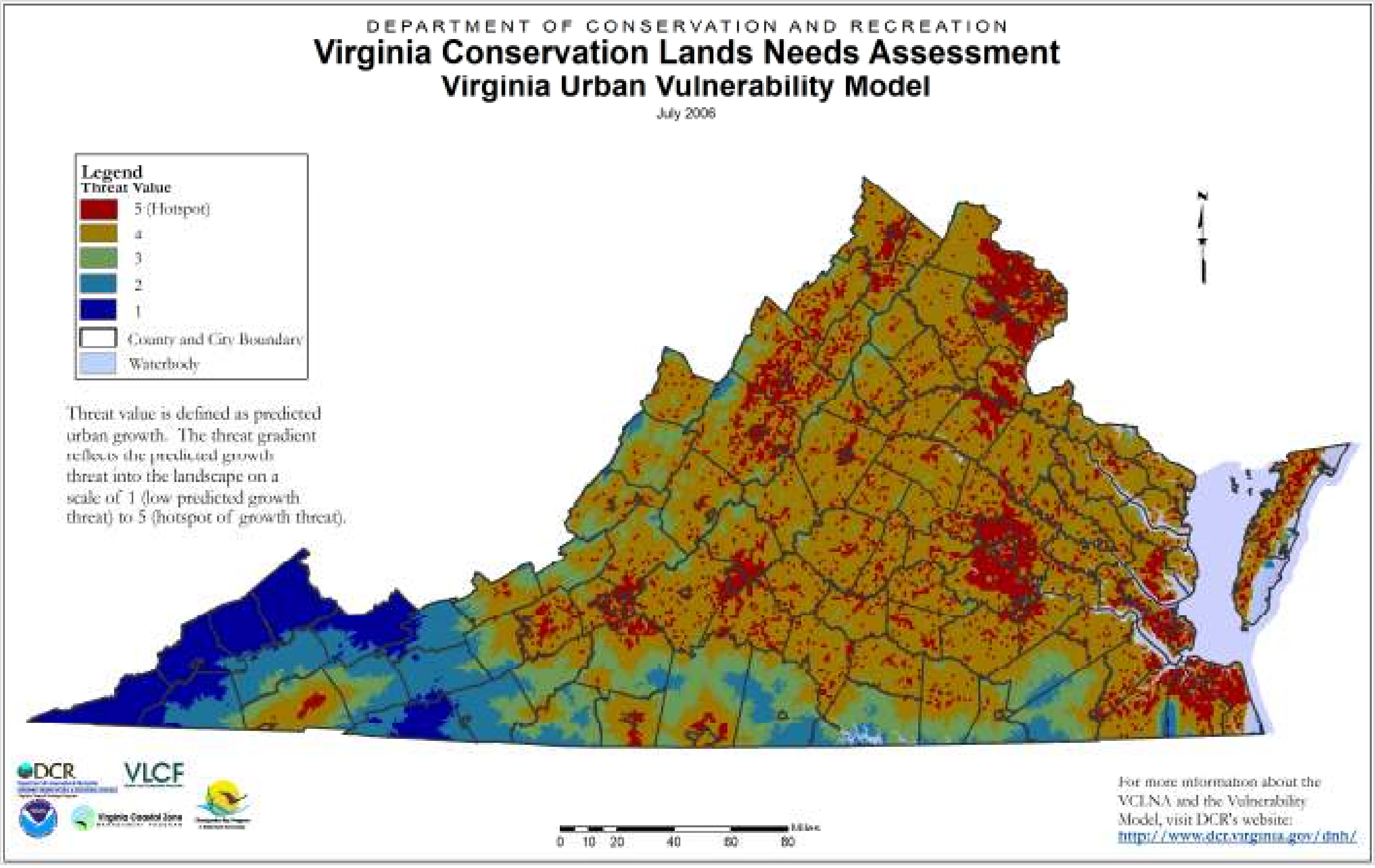

Figure 68. Virginia Urban Vulnerability Model.